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E L E M E N T S  
O F T H E  
B R A N C H E S  
O F  
N A T U R A L P H I L O S O P H Y

C O N N E C T E D W I T H

M E D I C I N E.

V I Z.



C H E M I S T R Y,		H Y D R O S T A T I C S,
O P T I C S,		E L E C T R I C I T Y a n d
S O U N D,		P H Y S I O L O G Y.

Including the Doctrine of the  
A T M O S P H E R E, F I R E, P H L O G I S T O N, W A T E R, &c.

T o g e t h e r w i t h

B E R G M A N ' S T A B L E S O F E L E C T I V E A T T R A C T I O N S,  
w i t h E X P L A N A T I O N S a n d I M P R O V E M E N T S.

By J. E L L I O T, M. D.

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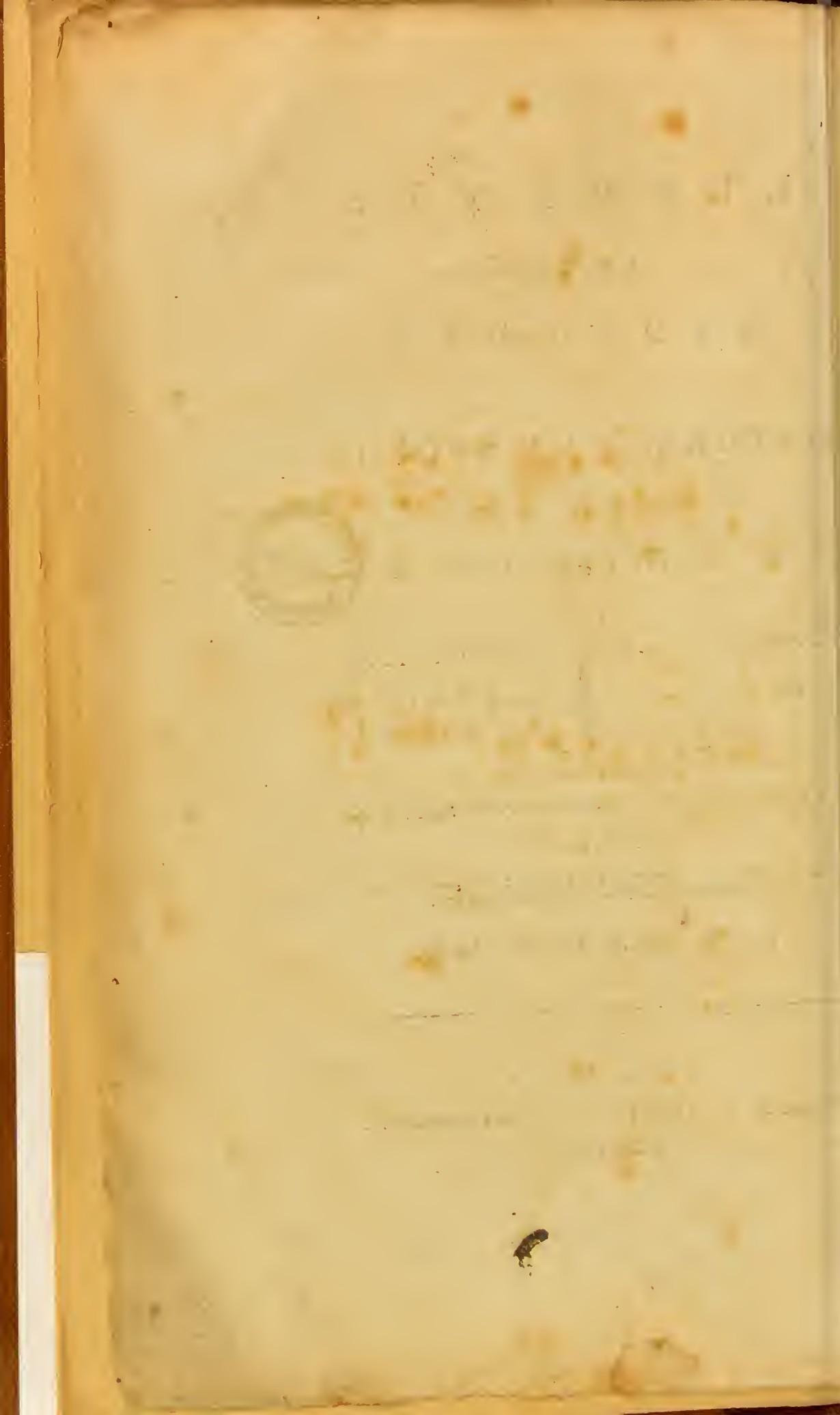
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L O N D O N:

Printed for J. JOHNSON, in St. Paul's Church-yard.

M D C C L V I I I .



T O  
SAMUEL FOART SIMMONS, M.D.

MEMBER OF THE ROYAL COLLEGE OF PHYSICIANS,  
L O N D O N ;

- A N D -

FELLOW OF THE ROYAL SOCIETIES  
OF LONDON AND PARIS.

S I R,

A Work intended for the instruction  
of the younger members of the medical  
profession seems to have a peculiar claim to  
the patronage of the ingenious Editor of the  
ELEMENTS OF ANATOMY. Give me leave,  
therefore, to dedicate to you the present  
performance. If the plan and the execution  
of it are honoured with your approbation, I  
shall be satisfied.

I have the honour to be,

With the most perfect respect,

S I R,

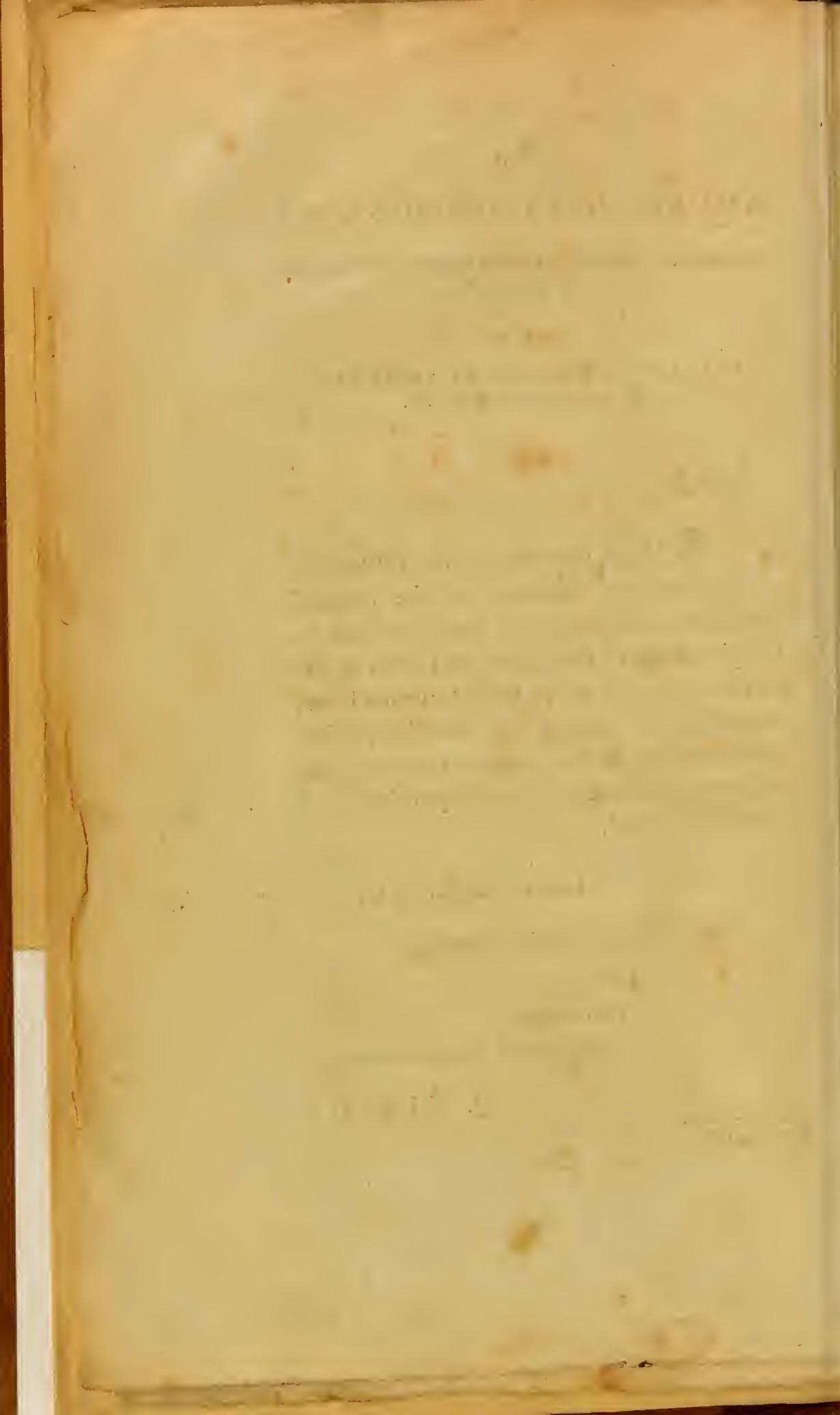
Your obliged

and devoted humble servant,

J. ELLIOT.

Newman - Street,  
Sept. 29, 1781.

A z



## P R E F A C E.

THE utility of natural philosophy to the medical practitioner must be sufficiently obvious when we consider that the faculties of the human body are intimately connected with those powers of nature which are in a more especial manner the objects of that science. Thus, vision depends on light; health is in a great measure regulated by the state of the atmosphere, and life itself depends on the purity of the air we breathe.

The student who has had the advantage of a regular education, is taught to consider philosophy as an indispensable branch of medical science. 'Tis by this he is led to understand, and reason about, the *causes* of diseases; and to form proper indications for the removal of them. By attending to the various states of the atmosphere, for example, he is enabled to account for and relieve a variety of symptoms that may chance to occur in the course of a disease, but which would puzzle and mislead one unacquainted with these matters. It is this, chiefly, that distinguishes the scientific and regular practitioner from the empirical.

It is to be lamented however that they who have not had such an education are in general but little acquainted with the principles of natural philosophy. For want of knowing what branches of it are necessary for their purpose, there are some who encounter the whole of the science, and thus are either deterred by the formidable bulk of the matter, from entering on the study at all, or, conceiving it to be of little or no use in their profession, conclude that the advantages to be derived from it will not compensate for the time and trouble they must necessarily employ in acquiring it. The latter objection particularly affects students in the pharmaceutical line, who, having generally other employment, have but little leisure for such pursuits. If such get acquainted with only the useful branches of philosophy, it is as much as can be expected from them.

My design therefore in the following work is to treat of those parts of philosophy which are connected with physic; and I shall endeavour to discourse of them in such a manner as that those for whom I write may not have much difficulty in understanding

standing me. Even gentlemen who are designed for physicians, will, 'tis presumed, find their advantage in the perusal, as it will enable them the better to understand the lectures of their professors, and prepare them for more learned treatises on these subjects.

The work is divided into three parts.

The first treats of CHEMISTRY; the *practical* part of which however the reader is by no means to expect. At first it was intended merely to have given the doctrine of affinities. But it was afterwards judged proper to add the accounts in the preceding chapters. If the reader has not already some knowledge of the chemical operations, he would do well to consult the writings of the celebrated M. Macquer; and M. Baume's excellent manual of chemistry, in English, with Mr. Aikin's notes.

The second part treats of OPTICS, ELECTRICITY, and such other subjects as were judged necessary to the design of the work. But the superfluous parts, even of these, are not entered upon. In the chapter on *optics*, for example, only so much of that science is given as is necessary to the understanding of the doctrine of *vision*.

In the last part it was only intended to give such a sketch of *physiology* as might be sufficient for shewing the connection and application of the subjects previously treated of, to the human body. The reader is referred for further information in these matters to the authors who have professedly written on this science, on pathology, and the other branches of medical theory.

From this account of the work it will easily be seen that it is intended rather as an *introduction to*, than a compleat treatise on the subjects mentioned; and the Author's end will be answered if it excites in the reader a *taste* for this useful kind of study. If the student has leisure, and a laudable ambition, he will not only perfect himself in these matters from authors of a superior rank, but even acquire a knowledge of those parts of philosophy, which, not being so immediately necessary, are not here discoursed of. For it need not be added, that an apothecary or surgeon, as well as a physician, will be more confid'd in by his patients, and be more generally and justly esteemed for his skill in his profession, as his learning is more extensive.

T A B L E

# TABLE OF CONTENTS.

## PART I.

### OF CHEMISTRY.

	Page
Introduction	ix
S E C T. I.	
<b>CHAP.</b> I. <i>Of Water</i>	2
II. — <i>Earth</i>	5
III. — <i>Salts</i>	11
IV. — <i>Air</i>	30
V. — <i>different kinds of Air</i>	47
VI. — <i>Phlogiston and its combinations</i>	63
VII. — <i>Fire</i>	75
S E C T. II.	
<b>CHAP.</b> I. <i>Of Volatilization</i>	87
II. — <i>Menstrua</i>	92
III. — <i>Extracts</i>	93
IV. — <i>Fermentation</i>	101
S E C T. III.	
<i>Of Chemical Combination &amp; Decomposition, &amp;c.</i>	103
<i>Bergman's Table of Affinities, &amp;c.</i>	139

## PART II.

### MISCELLANEOUS ARTICLES.

<b>CHAP.</b> I. <i>Of Optics</i>	143
II. — <i>Sound</i>	185
III. — <i>Hydrostatics</i>	193
IV. — <i>Electricity</i>	197

PART

x TABLE OF CONTENTS.

P A R T III.

	O F P H Y S I O L O G Y .	P a g e
Introduction		212
C H A P .	I. Of the Nerves and Muscles	215
	II. — the Moving Fibres	218
	III. — the Brain and Nerves	221
	IV. — the Circulation of the Blood	223
	V. — the Lymphatics	230
	VI. — the Primæ Viæ & Aliment	232
	VII. — the Blood	237
	VIII. — Nutrition	241
	IX. — the Glands	242
	X. — Perspiration	245
	XI. — Respiration	247
	XII. — Muscular Motion	251
	XIII. — the Effects of Air on the System	252
	XIV. — the Passions	259
	XV. — the Senses	264
	XVI. — Sleep	277
	XVII. — Generation	278
	XVIII. — the Progress of Life, and of Death	280
	XIX. — Recapitulation	281
	Postscript	289

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E R R A T U M .

Page 81 in the Table, *dele* Lunar crystal.

I N T R O -

## INTRODUCTION.

BEFORE I enter on the subjects proposed, it may be proper to premise the following particulars.

## 1.

All bodies, whether solid or fluid, are composed of particles too small to be visible to the naked eye. Thus, water is made up of such particles. We can divide a given quantity of that fluid into several portions; those again into others; each of which may again be subdivided, and so on till the portions cease to be visible. The least portions into which it can be divided are called *the particles of water*. The like may be observed of other bodies.

## 2.

The particles of some bodies are mutually attractive. You may understand the manner of this, by observing what happens when

xii      I N T R O D U C T I O N.

when two loadstones are placed near to each, the north pole of one being turned towards the south pole of the other; for they will draw, or attract one another, and by that means stick together, and it will require some force to separate them. In like manner the particles of bodies, by reason of their mutual attractions, stick or cohere. Some kinds of particles attract one another more powerfully than others. Thus, the particles of diamond cohere so strongly that they cannot be separated without a very great force. The particles of lead cohere less powerfully than those of diamond, and therefore are more easily separable. The particles of water cohere so weakly, that their separation is very easily effected.

3.

The particles of some bodies do not attract, but are on the contrary mutually repulsive; that is, they drive each other away. You may have an idea of this by turning the north or south pole of one magnet, to the same pole of the other; for you will find that

## INTRODUCTION.      xiii

that instead of rushing together, as before, they fly further asunder. The like is the case with particles of air, and of some other substances.

### 4.

The particles of some bodies attract those of others, as the magnet attracts iron. Thus, particles of water attract those of sugar ; hence water dissolves sugar. The particles of acids attract those of alcalis, and hence they unite. Particles of different kinds attract each other with different degrees of force. Thus, particles of spirit of wine attract those of essential oil ; but they attract particles of water, more than they do those of the oil. Also some kinds of dissimilar particles repel each other ; and there are other kinds which do not seem either to attract, or repel.

### 5.

Bodies may exist in three different states ; at least this seems to be the case with most substances. Thus, water with an heat sufficiently gentle, is *solid*, as when it is frozen. With a greater heat it is *fluid* ; which is the

xiv INTRODUCTION.

state in which we most usually observe it. But in an heat still greater, it is turned into vapour, or even becomes elastic like air. It may likewise be observed, that when water is in its *solid* state, its particles attract each other most strongly: when in its *fluid* state, very little; and when in its *elastic* state, they are, on the contrary, repulsive. The like may be observed of oil, of quicksilver, and many other substances. But different degrees of heat are required to produce these effects in different bodies, as will be more fully seen in the course of the work.

6.

Bodies gravitate, or tend towards the centre of the earth; and the force with which they gravitate, is in proportion to the quantity of matter which they contain. Thus, a quart of water contains twice as much matter as a pint of the same fluid, and therefore gravitates twice as much; or weighs twice as heavy: *gravity* and *weight* being synonymous terms.

7.

Different bodies, or substances, have different specific gravities. Thus, a pint of spirit

spirit of wine, weighs less than a pint of water, and therefore there is less matter in a pint of spirit, than in a pint of water. Hence spirit of wine is said to have less specific gravity than water.

On the contrary, a pint of quicksilver weighs heavier than a pint of water, and therefore contains more matter. Hence quicksilver is said to have a greater specific gravity than water.

To place it in another light, a pound of spirit of wine is greater in bulk than a pound of water; and a pound of water is greater in bulk than a pound of quicksilver. ~~For~~ there is an equal quantity of matter in a pound of spirit of wine, a pound of water, and a pound of quicksilver; but it is contained under greater or less bulk in one of these substances, than another. Thus also, a pound of wool may be comprised in a greater or less bulk, according as it is more or less pressed together; but whether the bulk be greater or less, the weight, or real quantity of the wool is the same.

## 8.

When the same quantity of matter is contained under a greater bulk, the body is  
I said

xvi      INTRODUCTION.

said to be *rare*; when in a lesser, *dense*: Thus, spirit of wine is rarer than water; but quicksilver denser.

Bodies will keep above those that are *denser* than themselves, provided the latter be fluid; but sink in such as are *rarer*. Thus, a cork floats upon oil; but lead sinks beneath it. Oil swims on the surface of water; quicksilver falls to the bottom.

9.

When a body is capable of being raised into vapour by heat, it is said to be *volatile*: when it cannot be thus raised, it is said to be *fixed*. Thus, spirit of wine is easily dissipated in vapour, and thence is said to be volatile: earth, not being capable of this, is said to be fixed.

So spirit of wine is said to be more volatile than water, because it is dissipated with less heat. Oil of vitriol is said to be more fixed than water, because a greater heat is required to raise it into vapour.

C H E M I S-

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# C H E M I S T R Y.

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## S E C T I O N I.

IT has been customary with writers on this art to begin their discourses with an account of the *chemical principles*. Of these principles, they say, all bodies are composed; and into them are capable of being again resolved. The old chemists reckoned five principles, viz. spirit, salt, oil, water, and earth. Later authors have added air; and some others: and different writers have varied them, either according to their own fancies, or the philosophy of the day. The doctrine of the four Aristotelian elements, earth, water, fire, and air, has, of late years been revived, and admitted by very eminent chemists. Earth, in particular, has been considered as a principle by all writers on this subject. But salts and oils are known to be compounds of other principles; and probably the like holds good also with the rest. For these, and other reasons we shall not enter on the subject of *principles*; and in the following chapters it is merely intended to give the reader ideas of some of those

chemical substances with which he may be supposed not to be so well acquainted.

## C H A P T E R I.

## O F W A T E R.

**W**ATER is a substance so well known, and with many of the properties of which we are so well acquainted from common experience, that much will not be required to be said concerning it.

It is transparent when pure, and without either taste, smell, or colour.

With a certain degree of cold it is converted into an hard or solid substance called ice, and with sufficient heat it is turned into vapour.

Water is a very general solvent. Salts of all kinds are dissolved by it, some in greater, others in less proportion; some more readily, others more slowly; and with the aid of heat, the solution is not only effected in less time, but in greater portion than otherwise. Pure gums, and mucilages are likewise dissolved by this liquid. Many substances which it cannot dissolve entirely, it can yet dissolve in part, as vegetable, animal, and many of the mineral substances.

Water cannot be compressed into lesser dimensions than it naturally occupies, or its compressibility.

sibility is so very little, that it needs not be here considered, being as nothing when compared to the compressibility of air; neither does it, like air, expand when a force compressing it is removed.

Vegetable, animal, and most of the mineral substances contain water when in their natural states: by far the greater part of the blood and juices of the two former is mere water. In salts and many other substances, water is also contained as a necessary ingredient.

Water is likewise contained in most substances, not in its fluid form, but in a state of combination, forming a solid body. What, for example, is more dry or solid than lignum vitæ? Yet if it be distilled, without any addition, in a retort, a vast quantity of water may be obtained. The like may be observed of the horns and bones of animals; of lime stones; and many other substances. The water being chemically combined with the other principles of these bodies, lost its *fluid*, and assumed a *solid* form. But when the union between these ingredients was destroyed, the water reassumed its fluidity.

As the greatest part of animal fluids is mere water, animal food must also contain this liquid in great proportion. Not to mention the liquids which we usually drink, the strongest of which are almost entirely water, the most solid of our

aliment contains this principle in very great quantity, as is plain from what was said above of the distillation of animal and vegetable substances, which make up almost the whole of our solid food:

Water cannot be obtained pure, because it will necessarily dissolve many particles of the various soils through which it passes. Hence the difference between river and spring waters, mineral waters, sea waters, &c. The purest of all is rain water. But for nice chemical purposes water is distilled.

When water is sufficiently heated it boils. The bubbles which then arise in it are water rendered elastic or turned into a kind of air, as will be shewn hereafter. If the pressure of the air be lessened or removed, the water boils with a less heat; but if the pressure of the air be increased, a greater heat is required to make it boil than otherwise. It is remarkable, that after water boils, it cannot be rendered hotter by increasing the heat. When water changes from a solid state, or ice, to a liquid form, cold is generated; and the like happens when it changes from a fluid to an elastic, or vapoury state; and heat is produced in the contrary cases. What has been said of water in this paragraph, holds good with oil, quicksilver, and other substances. But these things will be better understood after some other matters have been explained, wherefore I shall not at present enlarge on them.

## C H A P T E R II.

## O F E A R T H.

**B**Y earth we do not mean, with the vulgar; soil, or dirt; these being mixtures of earth, water, oil, salts, and other matters. The earth of chemistry is that substance which remains after all the other principles are expelled from a body by heat.

If a leaf be careful'y burnt, the salts, water, oil, and other principles of which it is composed, will be dissipated. But the earth, resisting the force of fire, will remain behind, still retaining the shape of the leaf; and therefore may also be said to be the basis of these other principles; by means of which they were the better enabled to sustain the form into which they were contrived.

The general character of earth is, that it is fixed, or incapable of being raised into vapour by any heat that we can apply. Some earths cannot even be rendered fluid by our fires, but retain their dry form in the most intense heat. By heat they are capable of being turned into glass, either alone, or by fusion with fixed alcalis.

Philosophers teach that there is but one kind of pure earth; which they therefore look upon as a principle; and call it *elementary earth*. All

the various earths which we are acquainted with, they consider only as pure earth adulterated with other principles; and imagine, that according to the substances with which it is alloyed, it forms earths of different kinds. These alloys, they add, are so intimately combined with the earth, that they cannot be wholly separated from it by any methods that we are yet acquainted with; and therefore the latter cannot be obtained pure.

It is, however, sufficient for our purpose, to consider earths in those states in which we usually obtain them. For whether their differences be original, or accidental, they have distinct and specific properties; and therefore ought to be considered as different substances.

## I.

## CRYSTALLINE EARTH.

CHEMISTS have given this name to diamonds, flints, crystal, and other hard, transparent, and infusible stones; which are only earth in a solid or crystalline form. They are known from others by their property of striking fire with steel. They are neither soluble in acids, nor fusible by fire. When mixed with alkaline salts, and exposed to an intense heat, they melt into glass. Could they be fused without such addition, the glass which they would form, would be much harder than any that art has yet produced.

## 2. CALCAREOUS

2.

## CALCAREOUS EARTH.

QUICKLIME is pure calcareous earth. It is obtainable from lime-stones, chalk, the shells of animals, marble, and some other substances, by calcination, or expelling their other principles by heat. It is infusible by our fires. In its natural state (as in chalk, the common absorbent or testaceous powders, &c.) it is combined with fixed air, and is then called *mild* calcareous earth. In its state of quicklime, it is freed from fixed air, and is then said to be *caustic*.

This earth is distinguishable from others, by its property of becoming quicklime, on expelling its fixed air by fire, or other methods.

It is likewise soluble in water, in its caustic state, and then forms lime water. In its mild state, it is not soluble.

It is dissolved by acids, either in its mild or caustic state. If in its mild state, it *effervesces*; the fixed air, which is set free by the acid, raising the liquid into a froth as it escapes. In its caustic state it cannot effervesce, because it contains no air to be extricated by the acids; the solutions therefore are exactly the same, whether caustic, or mild calcareous earth be used; the air, which constituted the difference between them, being expelled and dissipated when the mild earth is employed.

It neutralizes acids, and with vitriolic acid, it forms selenitis, or plaster of paris.

It expels volatile alcali from acids; and unites with sulphur; forming a kind of hepar sulphuris.

## 3.

## MAGNESIA.

LIKE calcareous earth, it may be had either in a mild, or caustic state, according as it is combined with, or free from fixed air. It may be obtained from Epsom, and some other salts, either by precipitation with an alcali, or by calcination, by which the acid is expelled.

It may be known from calcareous earth, by its forming sal catharticus amarus, with vitriolic acid; which is easily soluble in water; whereas calcareous earth forms with the same acid selenitis, which is insoluble in water, or so little soluble, as not in this case to be considered.

It may be precipitated from acids by volatile alcali.

It has less specific gravity than calcareous earth, especially when in powder,

## 4.

## ARGILLACEOUS EARTH.

It is contained in clay, and may be extracted by the vitriolic acid, with which it forms allum.

It

It may also be precipitated from allum by fixt or volatile alcali; and as this is the method by which it is usually obtained pure, it is also called *earth of allum*.

It is soluble in other acids: but its forming allum with the vitriolic is alone sufficient to distinguish it from other earths.

## 5.

## METALLIC EARTHS.

The substances remaining after the calcination of metals are called by this name. Thus, minium, rust of steel, and mercurius calcinatus; are metallic earths.

They have this remarkable and distinguishing property, that when fused with charcoal, or other inflammable matter, they become metals. Thus minium, treated in this manner, becomes lead; and mercurius calcinatus, quicksilver. This is called *reviving* them. By these means they may be known one from another, as well as in general from other earths. They may also be distinguished by other methods. Thus,

## CALX OF COPPER,

Combined with vitriolic acid, forms blue vitriol.

## CALX OF IRON,

Combined with the same acid, forms green vitriol.

## CALX

## CALX OF LEAD,

Combined with vegetable acid, forms saccharum saturni. This calx is also soluble in oils.

## CALX OF MERCURY,

Combined with nitrous acid, forms lunar crystal, or lunar caustic.

## CALX OF ZINC \*,

Combined with vitriolic acid, forms white vitriol: and so of others. They may also be characterized by their colour, and other sensible qualities, but the reviving them is frequently the most eligible method of discovering them.

The metallic earths, or calces, usually contain fixed or other air; which the phlogiston, by which they are revived, expels.

## ANIMAL AND VEGETABLE EARTHS,

OR the ashes of animal and vegetable substances, freed from their alkaline salts.

These are various, according to the nature of the subjects from which they are obtained. Thus some animal earths are calcarious; others not. Some are more easy of fusion; others less; and the like is the case with vegetable earths.

It would take up too much room to enumerate their different kinds; and much more the various other species of earth, mentioned by chemical writers;

\* Calamine, Tutty, &c. are calces of zinc.

writers; many of which are only compounds of those which have been mentioned. What has been said on this subject is amply sufficient to the purpose of the present work.

## C H A P T E R III.

## O F S A L T S.

SALTS are substances having taste, are soluble in water, and, for the most part, incombustible.

They are divided into acid, alcaline, and neutral; of each of which I shall give a separate account.

## I.

## O F A C I D S A L T S.

These are known from other substances by their sour taste, and by their changing syrup of violets, or other blue vegetable infusions red. When mixed either with one another, with alcaline salts, with metals which they can dissolve, or with water, they produce heat; with ice or snow, cold. They coagulate animal fluids; they powerfully attract water, insomuch that in the purest state in which we commonly use them they are combined with that fluid. Thus oil of vitriol is not pure vitriolic acid, but that acid and water. They have a strong tendency to unite with many other substances; as alcaline salts,

salts, earths, metals, animal and vegetable substances, &c. For this reason they are never found pure, but combined with some of these substances, from which they are obtainable by art. Thus, oil of vitriol is obtained from copperas; and vinegar from fermented vegetables. They are volatile, and resist putrefaction; they are usually divided into four kinds.

## I.

## THE VITRIOLIC ACID,

Or that which is obtained from copperas by distillation, from sulphur by burning, and from other substances. Thus, oil of vitriol, and spirit of sulphur by the bell, are vitriolic acid, or rather that acid combined with water.

It is distinguishable from other acids by the following properties: it has a stronger affinity to alcaline salts and earths than the other three acids, and therefore dislodges them from those bases, but cannot be dislodged by them.

When concentrated it excites a greater degree of heat with water, than any other acid.

It does not fume like the nitrous, or marine acids; nor has it either colour or smell, if pure.

With

With fixed vegetable alcali it forms vitriolated tartar; with fossil alcali, Glauber's salt; with argillaceous earth, alum; with calx of iron, copper, or zinc, green, blue, or white vitriol; with calcareous earth, selenitis; and with magnesia, Epsom salt: It is more fixed than the other three acids.

2.  
NITROUS ACID;

Or that obtained from saltpetre. Thus Glauber's, spirit of nitre, and aqua fortis, are nitrous acids, dissolved in water.

It may be known by the red colour of its fumes when it yields them, and by the greater degree of cold which it generates with ice or snow, than the other acids: When concentrated, it produces flame being poured on essential oils. With fixed alcalis it forms nitres, which may be known from all other neutral salts, by their property of deflagrating with any inflammable matter, in a sufficient degree of heat; and with volatile alcali, it forms a salt which detonates in a proper degree of heat without the addition of any inflammable matter. It is displaced from alcalis by the vitriolic, but not by the other two acids; but it attracts phlogiston more strongly than either of them. It is capable of existing in the form of air.

## 3.

## MARINE, OR MURIATIC ACID.

Spirit of sea-salt is what we understand by these terms ; it is distinguished by the following properties : . . .

When concentrated it is lighter than the vitriolic or nitrous acids ; of a yellow or straw-colour, and emits white fumes. It attracts metals more strongly than other acids ; with the fossil alcali it forms common salt, and with volatile alcali, sal-ammoniac ; it is dislodged from alcalis by the vitriolic and nitrous, but not by the vegetable acid ; it is obtainable in a separate state in the form of air.

## 4.

## VEGETABLE ACID.

Vinegar is most commonly understood by this term ; it is obtained from vegetables by fermentation.

When concentrated, that is, when distilled from verdigris, or from sal diureticus, or sugar of lead, by means of the vitriolic acid, or otherwise, it emits a most pungent smell.

It is dislodged from alcalis by all the three preceding acids ; with fixed alcali, it forms diuretic salts ; with copper, crystals of Venus ; and with lead, saccharum saturni.

Lemon-juice, cream of tartar, juice of sorrel, and others, are also vegetable acids ; they are for the most part weaker than vinegar, that is, are dislodged by it from alcalis. Cream of tartar forms Rochelle salt with fossil alcali, and soluble tartar with fixed vegetable alcali ; neither of which can be obtained by using vinegar. Cream of tartar is also in a solid state, contrary to the other acids ; all which attract water so powerfully as not to be usually retained in this form.

These are the acids usually considered by chemists ; but there are others : for example,

## 5.

## THE VOLATILE VITRIOLIC ACID,

Or aqua sulphurata of the London pharmacopœia, made by impregnating the vapours of spirit of vitriol with the fumes of some inflammable substance, or rather with phlogiston.

It has a very suffocating smell, and is difficultly concentrated ; it is dislodged from alcalis by the vitriolic, nitrous, and marine acids ; but the salts which it forms with those alcalis may, by exposing them to a gentle, but continued heat, be brought to the same state as those formed by the common vitriolic acid with the same alcalis ; and the like is the case with the acid itself. The acid is capable of being obtained

rained from the water by heat, in the form of a permanently elastic vapour, or air. It may be said to be the vitriolic acid volatilized by phlogiston.

## 6.

## THE PHOSPHORIC ACID.

Phosphorus is a compound of phlogiston and an acid. If the phosphorus be burnt, the acid remains behind, as is the case with sulphur. It may also be obtained by distillation, from the fusible salt of urine; and by other means.

It is the most fixed of any of the acids; for it may not only be evaporated to dryness, but will bear an heat capable of turning it into glass.

Distilled with charcoal, or other proper inflammable matter, it becomes phosphorus.

## 7.

## AQUA REGIA.

This is not a simple acid, but a compound of the nitrous, and marine; it is distinguishable from others by its property of dissolving gold.

## 8.

## SEDATIVE SALT,

Or the acid of borax; and which may be obtained from it by distillation with oil of vitriol.

It is solid, and vitrifiable; with the fossil alkali it recomposes borax.

The

The other acids are, the acid of amber, of ants, of animal fat, of the Swedish fluor, of sugar, and some others\*. But those already discoursed of are more than sufficient to the purpose of this work. Fixed air is also justly reckoned by the ingenious Mr. Bewly and others, among the acids.

## II.

## OF ALCALINE SALTS.

The most distinguishing characteristics of alcalis, are their acrid urinous taste; their turning blue vegetable infusions green, and their uniting with, and destroying the sour taste of acids. They are likewise capable of uniting with other substances: Thus, with oil they form soap; and with sulphur, hepar sulphuris. When combined with fixed air, or in their *mild state*, they cause effervescence with acids, and are capable of crystallization; but not in their *caustic one*. They are, like acids, obtainable by art, from the substances which contain them. See also the close of this article.

## I. FIXED VEGETABLE ALCALI.

It is made by burning land plants to ashes, in an open fire, pouring water on the ashes to dissolve the salts, then filtering and evaporating the solution to dryness; the alcali remains behind. Thus, salt of tartar, salt of wormwood, pearl ashes, and the like, are *fixed vegetable alcalis*.

C

It

\* See Bergman's Tables.

It attracts acids stronger than volatile alcali, earths, or metals; it therefore displaces those substances, but cannot be dislodged by them.

It is capable of converting *earths not otherwise fusible*, into glass by heat; and promotes the fusion and vitrescence of others.

In its caustic state, it dissolves vegetable and animal substances; and with expressed oil forms common soap. It is not volatile.

With vitriolic acid it forms vitriolated tartar; and with the nitrous acid, nitre.

It attracts water from the air, and thereby becomes liquid.

## 2. FIXED FOSSIL ALCALI.

Called also natron, and sal sodæ. It is obtained from sea-plants, in the same manner as the other is from land ones. It may also be extracted from common salt, Glauber's salt, and borax; and in some parts is found in its natural state. Kelp and barilla are fossil alcalis.

It differs from the vegetable alcali in several respects: It does not liquify in the air; it forms different salts with acids; thus, with the vitriolic it forms, not vitriolated tartar, but Glauber's salt. With marine acid, it forms common or sea-salt; and with the nitrous, nitrum cubicum. It is not volatile.

## 3. VOLATILE

## 3. VOLATILE ALCALI.

This is obtained, by distillation, from animal, and some vegetable substances, especially when putrid; and likewise from sal ammoniac by the addition of fixed alcali, or calcareous earth. Volatile sal ammoniac, and salt of hartshorn, are volatile alcalis; spirit of hartshorn, spirit of sal ammoniac, spirit of urine, &c. are volatile alcalis dissolved in water.

It differs in several respects from the fixed alcalis; it is displaced by them from acids, and also by calcareous earth.

It is volatile, and has a very strong pungent smell. With nitrous acid it forms a salt which detonates by itself in a sufficient degree of heat, called nitrous sal ammoniac.

With marine acid, it forms common sal ammoniac. It precipitates magnesia, earth of alum, and metallic calces from acids.

It may be obtained from the water with which it is combined in the form of a permanently elastic air; and if water be presented to this air, it presently absorbs it, and thereby becomes the same caustic liquid alcali as that obtained from sal ammoniac with quicklime.

## REMARKS ON ALCALIS.

All these alcalis in their natural state are not pure, but mild, or combined with fixed air. Hence, when they are mixed with acids, they cause an effervescence; which is nothing more than this air extricated from them by the acid, raising bubbles as it escapes through the liquid. If quicklime be mixed with them, it attracts the fixed air, and they then become caustic, or pure. Thus, the lixivium saponarium is the caustic fixed alcali, and the spirit of sal ammoniac, made with lime, is the caustic volatile alcali. Caustic alcalis violently attract water. Hence they are usually in a liquid state; but they may be obtained separate from the water. Thus lapis infernalis is the dry caustic fixed alcali; and alcaline air is the dry caustic volatile alcali. The caustic alcalis form the same neutral salts with acids as the mild ones; the air escaping when the latter are employed.

Volatile alcali contains more of the inflammable principle than the fixed. Hence it is, that it detonates with nitrous acid, when united in the form of nitrous sal ammoniac.

## 3.

## NEUTRAL SALTS.

They are formed by combining acids with alcalis or earths, as in the following Table :

## A C I D S.

	Vitriolic Acid.	Nitrous Acid.	Marine Acid.	Vinegar.	Cream of Tartar.
Fixed Vegetable Alcali.	Tart. Vitriol	Nitre,	Sal Digestiv.	Sal Diuretic.	Tart. Solub.
Fossil Alcali.	Sal Glaub.	Nitr. Cubic.	Sal Comm.		Sal Saignet.
Volatile Alcali.	Sal Amm. Vitriolic.	Sal Ammon. Nitros.	Sal Amm. Commun.	Sp. Minder.	
Calcareous Earth.	Selenitis.	Nitr. Calcar.	Liquidshell.		
Magnesia.	Sal Cath. Amar.				
Argillaceous Earth.	Alum.				
Calx of Iron.	Green Vitr.				
Calx of Copper.	Blue Vitriol			Cryf. Ven.	
Calx of Zinc.	White Vitr.				
Calx of Lead.				Sacc. Saturn.	
Calx of Mercury.		Lunar Crystal.	Merc. Corr. Sublim.	Keyfer's Mercury.	
Regulus of Antimony.					Tart. Emet.

Any neutral salt in the table is formed of the acid at the top of the column, and of the alcali, or earth on the left hand. Thus, marine acid

and fossil alcali, form common salt: nitrous acid and fixed vegetable alcali, nitre: and so of others.

The alcali, or earth of a salt, is called its *basis*; thus, volatile alcali is the basis of sal ammoniac; and magnesia is the basis of Epsom salt.

The phosphoric, and other acids, also form salts with alcalis and earths. But as they are not in use, I have not inserted them. Many of the spaces in the table are left vacant for the same reason; and some of those that are set down might have been omitted.

Neutral salts are usually divided into neutral, earthy, and metallic, according to their bases.

From most of the two latter kinds, the acids may be expelled by heat. But in those with alkaline bases this does not happen, or not so easily, by reason that their principles are held together by stronger attractions.

The salts with volatile alkaline bases are volatile; at least much more so than the others.

Neutral salts are for the most part capable of being crystallized; but the form of the crystals in each salt is different. In their crystalline state they contain a portion of water, which indeed is necessary to their crystallization. Hence they are stronger when this water is evaporated, and they are also more difficult of fusion.

## I.

## VITRIOLATED TARTAR.

It is composed of vitriolic acid and fixed vegetable alcali, remains dry in the air, and requires a great quantity of water to dissolve it. It decrepitates in the fire; is very difficult of fusion; is not soluble in spirit of wine; and its crystals are, for the most part, hexagonal prisms. Its taste is bitterish, and not very powerful. It cannot be decomposed by alcalis, nor, in the usual way, by acids. Fused with charcoal, it forms sulphur.

## 2.

## GLAUBER'S SALT.

It is a compound of vitriolic acid and fossil alcali. It dries into a white powder in the air; is soluble in an equal weight of water, and is easily fusible. Its taste is somewhat like common salt, but more bitter, and its crystals are hexagonal. It is not capable of being decomposed by alcalis, or by acids in the usual way. It yields sulphur, being fused with charcoal.

## 3.

## NITRE.

It is composed of nitrous acid, and fixed vegetable alcali. It deflagrates with inflammable matter in a sufficient degree of heat; is capable of being decomposed by vitriolic acid, when it emits red fumes; is easily fusible; has a sharp biting taste, and its crystals are hexagonal prisms.

## 4.

## CUBIC NITRE.

It differs from common nitre chiefly in the figure of its crystals, which are quadrangular, or rhomboidal.

## 5.

## COMMON SALT,

Is composed of marine acid, and fossil alcali. It is capable of being decomposed by vitriolic acid, when it emits white fumes. The nitrous acid likewise decomposes it. It is soluble in about an equal quantity of water, which dissolves as much of it when cold as by the assistance of heat. Its crystals are cubic, and very small. It decrepitates in the fire, and is difficult of fusion. Its taste is well known. If pure it remains dry in the air.

## 6.

## SAL DIGESTIVUS,

Differs but little from common salt. Its taste is less agreeable; and with vitriolic acid, it forms vitriolated tartar; whereas common salt forms with the same acid, sal Glauberi.

## 7.

## SAL DIURETICUS,

It is composed of the acetous acid and fixed vegetable alcali.

It is soluble in spirit of wine, and very easily so in water. It may be decomposed by heat, and by the vitriolic, nitrous, and marine acids, with

with which it forms tart. vitr. nitre, and digestive salt. It deliquesces in the air, and unites with gums and rosins.

## 8.

## ROCHEL SALT,

Is composed of fossil alcali, and cream of tartar. It is not deliquescent like the preceding salt. It may be decomposed by the mineral, and even vegetable acids; and if they are added to this salt, dissolved in water, the cream of tartar will be precipitated.

## 9.

## SOLUBLE TARTAR.

It is a compound of cream of tartar and fixed vegetable alcali. Besides its being less subject to crystallize, and to remain dry in the air, it may be known from Rochel salt, by the salts which it forms with vitriolic and other acids. Thus the vitriolic acid forms vitriolated tartar with this salt, and sal Glauberi with the Rochel.

## 10.

## VITRIOLIC SAL AMMONIAC,

Is composed of vitriolic acid, and volatile alcali. It is decomposed by fixed alcalis, and calcareous earths, which presently discover its volatile alkaline basis.

It is difficultly soluble in water, and not at all in spirit of wine.

## I I.

## NITROUS SAL AMMONIAC.

It is a compound of nitrous acid and volatile alcali. It attracts water from the air; is soluble in spirit of wine, and may be decomposed by fixed alcalis and calcareous earth.

It may also be decomposed by vitriolic acid, when it emits red fumes.

It is easily fusible, and may be known from all other salts, by its property of deflagrating in a sufficient heat, without addition.

## I 2.

## COMMON SAL AMMONIAC,

Is a compound of marine acid, and volatile alcali. Its basis may be detected by fixed alcalis, or calcareous earth, and its acid by oil of vitriol, in the form of white fumes.

It differs also from the vitriolic sal ammoniac in being soluble in spirit of wine.

Dissolved with common salt in water, it produces cold. It is volatile.

## I 3.

## VEGETABLE SAL AMMONIAC.

It is formed of volatile alcali, and vegetable acid. Thus spiritus Mindereri is this salt in a liquid form. But it may be obtained dry by proper methods.

Its

Its alcali may be detected by fixed alcalis, and calcareous earths; and its acid by either of the mineral acids.

It easily deliquiates, and is copiously soluble in water, and in spirit of wine.

## 14.

## SELENITIS.

It is composed of vitriolic acid and calcareous earth, and is also called gypsum, and plaster of paris.

It is difficultly soluble in water, and requires a very large quantity for that purpose.

Its earthy basis is precipitated by fixed alcalis. But acids do not decompose it. Its acid however, may be discovered by examining the salt formed by the added fixed alcali, which will be vitriolated tartar.

## 15.

## SAL CATHARTICUS AMARUS,

Is a compound of vitriolic acid, and magnesia. It is readily soluble in water, and in great quantity. But it is not fusible.

Its basis may be precipitated by volatile alcali, as well as by fixed, in which respect, among others, it differs from selenitis, and from salts formed by other acids with calcareous earth.

Its acid may be detected by the vitriolated tartar which it forms with fixed alcali.

## 16. ALUM.

## 16.

## ALUM,

It is formed of vitriolic acid, and argillaceous earth. It is easily fusible, and dissolves in about four times its weight of water. It has an astringent taste, and its crystals are eight sided pyramids.

Its basis may be precipitated by fixed or volatile alcali; and its acid may be known by the vitriolated tartar which it forms with fixed vegetable alcali.

## 17.

## GREEN VITRIOL.

It is composed of vitriolic acid and calx of iron; and is also called *salt of steel*, and copperas.

Its crystals are green, transparent, and rhomboidal. Its acid may be detected by the salt formed in the addition of fixed vegetable alcali, and the basis precipitated thereby, may also be examined and discovered. See earths,

## 18.

## BLUE VITRIOL,

Is composed of vitriolic acid, and calx of copper. Its crystals are blue, and their taste very acrid and ungrateful.

Its principles may be discovered by the means directed in the last article.

## 19. WHITE

19.

## WHITE VITRIOL.

It is a compound of vitriolic acid and calx of zinc. Its crystals are white and small, resembling sugar in appearance. Their taste astringent and sweetish. Its principles may be detected as in green vitriol.

20.

## SUGAR OF LEAD.

It is composed of acetous acid, and calx of lead.

It is easily soluble in water; of a sweet astringent taste; and its crystals are small and white.

It may be decomposed by either of the alkaline salts. Its acid forms diuretic salt with fixed vegetable alcali, and its precipitated basis may be detected by referring to the chapter on earths.

21.

## MERCURIUS CORROSIVUS SUBLIMATUS.

It is a compound of marine acid, and calx of mercury; it is soluble in spirit of wine; its taste is nauseous and brassy, and it is volatile. Its crystals are small and white.

Its principles may be detected by adding alkaline salt; examining the precipitated earth, and the neutral salt produced, as directed in the four preceding articles.

It

It would be tedious, and unnecessary to the design of this work, to go through the whole number of neutral salts capable of being formed by acids, alcalis, and earths. Every solution of a metal or earth in an acid may be considered in this view; being only the salt formed by the acid and its basis, dissolved in water; and the number of acids and bases is very great. Those salts which have been considered, are sufficient to give the reader an idea of neutral salts in general; and, together with what will be said in the following chapters, will enable him to understand the nature, as well as to discover the composition, of others.

## C H A P T E R IV.

## O F A I R.

**A**S the doctrine of air constitutes one of the most important branches of medical philosophy, it will be necessary to enlarge on it.

Air is a fluid surrounding the globe of the earth to a very considerable height, forming what is called the *atmosphere*.

In its usual state it does not discover itself to any of our senses; and hence, with the vulgar, *air* and *nothing*, are synonymous. When it is in motion, it is perceptible to the feeling and hearing; and also (by its effects in moving light and flexible bodies:) to the sight, under the notion of *wind*.

If a bladder be filled with air, it may be rendered very obvious to the touch. For the hand will find it impossible to compress the bladder, as when in its empty state. Also if you attempt to fill a vessel with water, or any other substance, you will find it impracticable, unless at the same time you let out a proportionable quantity of air; as may be observed to great advantage in vessels with narrow necks. These are not only proofs of the *existence* of air, but also of its *impenetrability*; or property, in common with water, and other bodies, of not suffering any other substance to possess the space which it occupies, otherwise than by removing it from that space.

If a bladder filled with air be weighed with a very nice pair of scales, and if it be weighed again after the air is forced out of it, it will be found lighter than before; and if the bladder be very large, the difference of weight will be several grains. From hence it appears, that the air is also *heavy*; the only difference between water and it, in this respect is, that water is heavier than air; in the same manner that quicksilver is heavier than water.

If an almost empty bladder, carefully closed, be put into the receiver of an air-pump, and then the *air* be gradually withdrawn from the receiver, the bladder will begin to swell, and at length

length appear full blown. But if the air be again gradually let into the receiver, the bladder will lose its bulk by degrees till it appears as empty as before.

From hence it appears, that the same quantity of air is capable of expanding itself into a greater bulk than that under which it usually exists. To understand the reason of this, it is to be observed, that the air naturally contained in the receiver presses upon the bladder on every side, and thereby compresses it into its seemingly almost empty state. When part of the air in the receiver was pumped out, the compression of the bladder became less than before ; and therefore the air within it was suffered to expand itself, and thereby swell the bladder. As more air was drawn out, and the pressure upon the bladder became less, the included air had still greater liberty to expand, till at last the bladder was perfectly distended. When the air was again let into the receiver, and the compression of the bladder began to be increased, the included air was forced into lesser bulk. As more air was let in, and the pressure became greater, the included air was forced into still less dimensions, till at length the bladder appeared as empty as before.

Air therefore, naturally expands ; and it is kept in its usual bulk or dimensions by the pressure of other air incumbent on it ; and in this

this view its elasticity is also called *its spring*. A steel spring, for example, if bent by means of four pound weights, continues bent to the same degree as long as the weights remain on it. If one of those weights be removed, the spring in part recovers itself, or becomes less bent. If another of the weights be removed, it recovers itself more; if a third weight be removed, it recovers itself still further; and if the fourth be also removed, the spring will be quite unbent, or in its natural state. But if the weights be afterwards added in the order that they were taken away, it will again be bent by the same degrees, till it returns to the state it was in before; and will continue in that bent state as long as the weights remain on it.

The air around us therefore is in a compressed state, or forced into less space than it would occupy if it was free. The cause of this compression will be seen when we treat of the weight of the air. The fact alone is sufficient for our present purpose.

Over the mouth of a basin, or other proper vessel, tie a piece of bladder or thin parchment, so that no air may pass either to or from the vessel; and let it be sufficiently tight, yet so as that it may be bent: if you place a weight on this cover, you will find that it will be pressed down into an hollow, or below the level of the

D brim

brim of the vessel ; and if you add more weights, this will happen in a still greater degree. But if the weights be removed, the cover will return to a level with the vessel's brim, as at first.

From hence it appears, that air is capable of being compressed into lesser dimension or space than that which it usually possesses ; and that it returns to its wonted bulk, when the compressing cause is removed. Thus, if to the four weights, already compressing the spring in the last case, a fifth should be added, the spring will be bent still further than it was before ; and if a sixth be added, this will take place in a yet greater degree ; but if the two additional weights be removed, the spring will return to the same state as before they were added.

Air therefore when compressed endeavours, like a spring, to recover itself ; and that endeavour is stronger, as the compressing force is greater. If a tube be stopt at both ends with wads of paper, and one of these be forced into the tube by a rammer, the air between the wads will be compressed ; and in its endeavour to recover itself, will force out the paper at the farther end. So if a blown bladder be violently compressed, the air contained in it, by endeavouring to recover its former dimensions, will burst the bladder ; and many other instances of the kind will occur. Thus the phænomena

of

of the air-gun depends on this property of the air.

Squeeze almost all the air out of a bladder, and close its neck with a string ; if the bladder be brought near the fire, it will swell ; and, if the heat be sufficient, will be puffed up like a bladder full blown. Remove the bladder to a cold place, it will continually contract in its bulk, till it appears as empty as before.

Also fill a bladder with air in a warm room, or in the summer, and remove it to a colder room, or keep it till winter, you will find that it is contracted in its dimensions. Restore the bladder to the warm room, or keep it till summer, it will appear as bloated as before.

From hence it appears, that the same quantity of air is capable of being expanded, or increased in bulk by heat, and contracted, or lessened in bulk by cold ; or in other words, that its elasticity or spring is increased by heat, and weakened by cold. It will be shewn hereafter, that the elasticity of the air probably depends entirely on heat.

Having premised these properties of air, we may proceed to explain the general construction of the atmosphere.

Air is a fluid, reaching from the surface to many miles above the earth, and encompassing the whole globe, as hath been amply demonstrated by philosophers.

The upper part of this air is expanded into its utmost or natural bulk. The air next under this, is pressed upon by the weight of that above it; and therefore is forced into lesser dimensions than it would have if not thus pressed upon. The air next under these will be still more pressed, by reason of the weight of both the above-mentioned quantities of air on it, and therefore will be forced into a bulk still less than that which is next above it; and in like manner we may imagine of the air beneath this; and so on continually, till we arrive at that which rests upon the surface of the earth, which will be most compressed of all.

To obtain a clearer idea of this matter, take a quantity of wool, and place one lock or fleece of it upon the ground, that fleece will be of its natural bulk. If upon this fleece you lay another, the upper one will be of its natural bulk; but the under one will be compressed into lesser dimensions, by the weight of that which is upon it. If a third fleece be added, the under one will be compressed still more, and the second will be in the same state as that was just before. By adding continually to the pile, the undermost

most fleeces will be still more pressed upon by the increased weight of those above, and therefore be forced into still less dimensions ; and those which are nearest to the bottom, will of course suffer the greatest compression.

If now you remoye these fleeces one by one, those which successively become uppermost will recover their natural bulk, and the pressure upon the under ones will also become less in proportion. When they are all removed, that which was undermost will also recover its natural dimension, or return to the same state as before the experiment.

The air above presses on that which is beneath, in like manner as hath been shewn with regard to the fleeces of wool. The uppermost air is expanded into its natural bulk, and that beneath is continually more and more compressed by the weight of that which is above, till we arrive at the earth's surface, where the compression is greatest of all.

From hence it appears, that if a bladder be filled with the air at the top of the atmosphere, and brought down from thence towards the earth, it will, by reason of the continual increase of compression, be forced into less and less dimensions ; and the bladder will therefore appear to become more and more empty,

Also if a bladder almost empty of air, such as it is at the bottom of the atmosphere, be carried upwards, it will swell in proportion to the ascent, by reason that a less weight is incumbent on it than before. You may prove both these cases by carrying a bladder not full blown from the bottom to the top of an high mountain, for it will be larger when you arrive at the top ; and on the contrary, if you fill the bladder at the top of the mountain, it will appear to be partly empty when you descend to the bottom. Thus the bottom fleece of wool, if removed higher to the top, will enlarge its dimensions ; but if one of the middle fleeces be placed at the bottom, its dimensions will become less,

If you weigh a bladder partly emptied of air, and then by means of heat, or the air-pump cause the air in it to swell or expand, it will not weigh heavier than it did before : for the quantity of air which the bladder contained, was the same when it appeared full as when it seemed partly empty. Thus, a fleece of wool in its natural state does not weigh heavier than when squeezed or twisted up into an hard ball, the quantity of wool being the same in both cases.

From hence also it is plain, that if a bladder be filled with air as it is in its expanded state at the top of the atmosphere, it will not weigh so heavy

heavy as if filled with air at the bottom; because in the latter case a greater quantity of air is contained in the same bulk. Thus the same bladder filled with wool put in lightly, will weigh lighter than if filled with wool in a compressed state. Also if the bladder be filled with air, anywhere in the middle of the atmosphere, it will weigh heavier than if filled at the top, and lighter than if filled at the bottom; for reasons which will be obvious from what has been said.

When the same quantity of air is expanded into a greater bulk, it is said to be *rare, rarefied, expanded*, or to have *a less specific gravity*. When compressed into lesser dimensions, it is said to be *dense, condensed*, or to have *a greater specific gravity*, agreeable to what was said on these points in the definitions.

From this general account of the structure of the atmosphere we may be enabled to reason concerning its pressure,

I shewed before that the air was *heavy*; and the compressed state of the air near the earth has also been shewn to be an effect of this property. Imagine a square to be drawn on the ground which measures every way a foot, and suppose a column of air of the same dimension with this square, reaching from the ground to the top of the atmosphere, it is demonstrated by philosophers that it would weigh

2000 pounds. The whole surface of the earth contains 554780000000000 of such square feet, and therefore the pressure or weight of the whole atmosphere on the earth's surface is 110956000000000000 pounds. The surface of the human body contains about 14 square feet, the air therefore presses on it with a weight equal to 28000 pounds; and in like manner it presses on other bodies, according to the quantity of their surface. This pressure however is not usually sensible, because the air contained in bodies, and compressed by that weight, equally resists it by its elastic force. Thus, a steel spring bent with a four pound weight resists any farther flexion by that weight. But if the spring should happen to be weakened, the weight would then bend it more; if it should be strengthened, its flexion would on the contrary be less. In like manner, if the resistance of the air contained in bodies, becomes either greater or less than the pressure of the atmosphere on them, the superior or inferior force of that pressure would then become manifest. We must however except those bodies which are of so firm or rigid a texture as not to be influenced by these circumstances. Thus air may be very much rarified or condensed in close metallic or other vessels; and these vessels will not manifest any signs either of contraction or expansion: tho' even these will be burst by air, when sufficiently condensed in them.

In the vessel covered with bladder, before described, we find that the internal and external air press equally against the bladder, and therefore its surface remains level with the brim of the vessel. If the bottom of the vessel be warmed, so as to heat the included air, and thereby increase its elasticity, the bladder is driven upwards ; which argues that the resistance of the included air is become greater than the pressure of the external.

On the contrary, if, we place the vessel in a mixture of salt and snow, so that the internal air may be cooled, and its spring weakened, the bladder will be driven downwards, a proof that the pressure of the external is become greater than the resistance of the internal air.

If this vessel be put under an air-pump, and, by means of a hole properly contrived, the air which it contains be drawn out, there is said to be a *vacuum* made in it, by reason that it is empty of all sensible matter. The resistance within the vessel, to the external air, is therefore entirely destroyed, and the pressure of the latter will be seen to be so powerful, that it will break the bladder and rush into the vessel with a great noise, in order to fill up the vacuum.

If part of the air be sucked out from a vial, the resistance of the internal air will be less than  
the

the pressure of the external ; or to speak in the language of philosophiy, a partial, or imperfect vacuum will be made in it. The lip therefore will be pressed into the vial by the external air, nor can they be separated without some force, and then the air rushes in to fill up the vacuum.

If the piston of a syringe be withdrawn, a partial vacuum will be made ; and the air will rush in at the orifice of the pipe as fast as possible, to restore the equilibrium ; or if the pipe be placed in water, the pressure of the air on the surface of that liquid will drive the water into the syringe.

But the pressure of the air is in no instance more conspicuous than in the barometer. If a slender glass tube, a yard in length, be filled with quicksilver, then turned upside down, with the open end in a basin of that metal, the quicksilver will run out of the tube into the basin, till it has sunk about five or six inches, but after that it ceases to flow : for it is supported at the height of about thirty inches by the pressure of the air, and this is the method by which we know the exact weight of a column of air, reaching from the bottom to the top of the atmosphere ; for the quicksilver is supported in the tube, by the resistance or pressure of a column of air, equal in diameter to that of the quicksilver, and reaching from the mouth of the tube (or, which is the

same thing in effect, the surface of the mercury in the basin) to the upper part of the atmosphere, and therefore the weight of such a column of air is exactly equal to the weight of the quicksilver in the tube, they precisely balancing each other; and if the tube was a square foot in width, the weight of the mercury, and in course that of the air, would be at least two thousand pounds, as mentioned before.

But the atmosphere is not always of the same height at the same place, or in other words, a column of air of the same diameter, does not always weigh exactly the same; for the atmosphere, like the sea, is subject to fluxes and perturbations, which will therefore cause it to be higher, and heavier at some parts of the earth than at others; and, at different times, in the same place. Thus, sometimes the quicksilver is supported at the height of thirty-one inches, at other times only at twenty-eight, and at others, somewhere between these; and the use of the barometer is to shew, by the height of the quicksilver, the weight of the air. But another use of the barometer is, to shew the state of the weather with respect to rain. When the air is heavier, it is also denser in course, and therefore the clouds will be borne up higher, and prevented from falling; hence the weather is at those times fair. But, when the atmosphere is lighter, the clouds

clouds are suffered to descend to the earth, and then we have rain, snow, &c.

It may be proper to observe that the air does not press directly downwards only, but every way alike. Thus, if a vacuum be made in a vessel, and its mouth be held downwards, the air will press on, and rush into it as well as if its mouth were upwards. For every part of the air at the bottom being pressed by that above, wherever there is a vacuity, the air around, in consequence of the pressure, will rush thither, and thereby restore the equilibrium.

The atmosphere is always moist in a greater or less degree, from the quantity of aqueous vapour which it contains. Thus, if you expose salt of tartar to the air, it will in a little time attract so much water from it, as to make it liquid, and it will be dissolved in greater or less time, according as the air happens to be more or less moist. The hygrometer, or instrument for measuring the moisture of the air, is constructed on this principle. An oat beard, when the air is dry, is twisted up, and therefore shorter; but when the air is moist, it is relaxed, or un-twisted, by reason of its attracting that moisture; and the length which it acquires in consequence thereof, indicates the degree of the moisture of the air.

The air has also a power of dissolving bodies in the manner of a menstruum, according to the present philosophy. If a salt of any kind be put into water, the water will dissolve it; and the solution will be hastened by agitation and heat. In like manner, if water be exposed to air, the air dissolves it, and if the air be hot, and the water agitated by wind, or any other cause, the solution takes place the sooner. Water when hot will also dissolve a greater quantity of a salt than it can retain when cold; and hence it crystallizes. In like manner air, in a hot summer's day, dissolves a large quantity of water, which it deposits in the night, or when cold, in the form of dew. Vegetable, animal, and most other substances are also capable of being dissolved by air. Thus, the flesh of a dead animal, exposed to the air, will, in time, entirely disappear.

For these reasons, and also on account of the steams and exhalations which are continually rising into the atmosphere, from the bowels of the earth, it is plain that air, any more than water or earth, cannot be obtained pure; and it is also evident, that on account of the various natures of these exhalations, and of the winds which bring them from different parts, the air will be adulterated in a different manner, not only at different parts of the earth, according to  
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the nature of the soil, but also, at different times, in the same part.

When air is rarefied in any particular part of the atmosphere, by heat, or otherwise, the air around will flow towards that part, to restore the equilibrium; and this motion or flux of the air we call wind.

The effects of air, in its different states, on the body, will be considered in a future and more proper place.

## C H A P T E R V.

## OF THE DIFFERENT KINDS OF AIR.

TILL within these few years past, philosophers had no idea of any more than one kind of air. They considered it as an element; and whatever differences they found in air, in different circumstances, they imputed entirely to the admixture of foreign matters, from which the air was capable of being obtained in the same pure state as before. They reasoned about air then in the same manner as we do now concerning water. The industry of philosophers however, has set us right in these matters.

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I.

## OF COMMON AIR.

There are certain processes in chemistry, which the later writers on that art term *phlogistic*. Thus, *combustion*, or the burning of bodies, is a phlogistic process; so likewise are respiration, and some others. The theory of these processes will be explained more at large in a future chapter. The effect only, will be sufficient to illustrate the subject in hand.

If a candle be burnt, or an animal breathes, in a given quantity of air, it is well known that the one will soon be extinguished, and the other die.

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die.

die. These effects will happen sooner, according as the quantity of air is less. The facts may easily be proved by putting the candle, and the animal, in glass vessels, of proper sizes, filled with common air.

The effect which these processes have on air, is to diminish it in bulk. If we fix a lighted candle into an inverted glass receiver, and immediately place its mouth in water, we find, that when the candle is extinguished, and the air in the receiver cool, the water will rise up into the neck of the vessel, higher than it did at the beginning of the process, and therefore the air was diminished.

If an animal be put into the vessel, and suffered to remain there till it expires, the air will be still further diminished, than by the burning candle. But when the diminution of air, by these processes has proceeded to a certain degree, it cannot be carried any farther.

The cause of this diminution is *phlogiston*; which is imparted to the air by the candle, and the animal, in those processes. The air attracts the phlogiston by means of a superior affinity, as will hereafter be shewn; and on this principle combustion, &c. depend. When air becomes saturated with phlogiston, it is incapable of imbibing more. It can therefore be no farther diminished;

diminished; and is no longer fit for supporting animal life, or for other phlogistic processes.

From hence it appears, that with respect to respiration, &c. air may be considered as better, or more pure, in proportion as it is freer from phlogiston. We shall consider this subject again, under the article of *dephlogisticated air*.

## 2.

## OF PHLOGISTICATED AIR.

Air which has been injured by respiration, combustion, &c. in the manner already described, is thus called. If air be fully saturated with phlogiston by those processes, it is said to be compleatly *noxious*. A candle is instantly extinguished, and animals presently die in this air. But we shall have occasion to speak of it further in the following article :

## 3.

## OF DEPHLOGISTICATED AIR.

It has long been known that nitre is capable of maintaining the combustion of inflammable bodies, as well as air.

If lighted charcoal be placed in proper exposure to air, it will continue to burn till the whole is reduced to ashes.

If nitre be mixed with charcoal, and the powder, already kindled, be put into a close vessel,

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the combustion will be as compleat as if the charcoal had been exposed to the open air; though without the assistance of the nitre, the charcoal would presently have been extinguished in that confined situation. Nitre, therefore, has the same effect in this process as air.

The reason of this was not known till lately. But Dr. Priestley has found that by means of heat, air may be expelled from nitre, of the same nature with that of the atmosphere, but much more pure. A candle will burn, and animals live in it, four or five times as long: and therefore it is freer from phlogiston than common air.

When nitre is burnt with a combustible body, a quantity of air is set at liberty, and resumes its elastic or expansive state. This is the dephlogisticated air above spoken of, combined with the phlogiston of the inflammable substance. The explosions of gunpowder, and other nitrous mixtures, depend on this air.

Nitre is not the only substance from which dephlogisticated air may be extracted. It may be obtained from many other bodies, merely by heat. But different substances yield it in different proportions; and it is also more pure, when obtained from some bodies than from others.

After

After minium has yielded as much of this air as it will by heat, if spirit of nitre be added, a fresh quantity may be procured. If more spirit of nitre be added to the remaining calx, there will be a still further yield; and the operation may be continued, with the like result, as long as any of the minium remains. And there is no earthy substance from which this kind of air may not be obtained by a like treatment.

But the vitriolic acid answers this purpose as well as the nitrous; and from every earthy substance on which that acid can act, dephlogisticated air may be obtained.

As this air is so much purer than common air, there is reason to hope that great benefit will accrue to mankind by the medicinal use of it, in disorders where the phlogistic principle abounds in the constitution, by breathing it instead of common air. It has already been prescribed in those cases, with good effect. In combustion also, it may be employed to advantage. If a fire be blown with this air, the heat is prodigiously more intense than when common air is employed.

Dephlogisticated air, being only a pure kind of common air, it is plain that it only requires a proper addition of phlogiston, to make it of the same goodness with that of the atmosphere. Com-

mon air, in respect to purity, is between phlogisticated and dephlogisticated air; these three kinds differing from one another only in being more or less free from the phlogistic principle.

As the atmosphere is constantly exposed to animal respiration, combustion, putrefaction, and a variety of other phlogistic processes, it must be continually receiving injury; and therefore if there were no contrivance in nature for purifying it, it would long before now have been rendered unfit for these processes. Animals could not live, nor could fires exist in it. But Dr. Priestley has discovered, that air thus rendered noxious, is purified by vegetables growing in it. And by prosecuting that discovery, he has found that they perform that salutary effect by means of the *sun's light*. If a plant grows in the shade, it rather adds phlogiston to the air; but if it be placed in the light of the sun, it attracts phlogiston from the air, in a surprising degree, mending it out of all proportion beyond the injury it does to it in the shade \*.

Animals and vegetables therefore, counteract each other's effects in this particular; and hence is discovered to us an use of the vegetable creation, which meer reason could never have led us to suspect.

Dr.

\* See also Dr. Ingenhouz's treatise on this curious subject.

Dr. Priestley also discovered that phlogisticated air may be purified by agitation with water. Hence we perceive a very important use of winds; and of storms at sea. Philosophy daily teaches us, that those natural effects which appear to us to be most hurtful, are instituted for very important and useful purposes in the creation.

## 4.

## OF NITROUS AIR.

If spirit of nitre be added to iron, or any other phlogisticated substance which it can dissolve, there will fly off from it, during the solution, an elastic vapour; which being caught in proper vessels, is what is usually called *nitrous air*.

If this air be mixed with common air, a considerable degree of heat succeeds, together with a turbid redness, and *diminution of their bulk*. The latter circumstance has been happily applied by Dr. Priestley to a very useful and important purpose.

He found that the diminution was greater, in proportion to the purity of the common air employed; and hence has established a test of the goodness of air, or the degree in which it is proper for respiration, &c. Instruments are now used for this purpose, as thermometers are for

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discovering the temperature of bodies ; they are called *eudiometers*.

If common air be diminished as far as it is capable of, or rendered perfectly noxious, nitrous air has no effect on it ; neither does it diminish any other kind of air, but common air not completely phlogisticated.

Nitrous air consists of nitrous acid, and phlogiston. The air takes the latter ingredient from the acid, and thereby becomes diminished, in the same manner as when it is phlogisticated by the processes of combustion and respiration ; the manner of which has already been described. The turbid redness is owing to the nitrous acid, now separated from the phlogiston, and appearing in its usual form of red fumes.

Nitrous air has also the property of preserving substances kept in it from putrefaction ; but it is totally unfit for respiration, animals presently dying in it.

## 5.

## OF INFLAMMABLE AIR.

If iron be dissolved in the vitriolic or marine acids, an elastic vapour arises, which being mixed with common air, takes fire at the flame of a candle, and therefore is called *inflammable air*.

This

This kind of air may also be produced by putrefaction, and a variety of other methods; and is sometimes found ready formed. Thus, when coal mines take fire, it is owing to a quantity of inflammable air exhaled from the mineral substances, and mixing with the common air in the mine. It is unfit for respiration, &c.

## 6.

## OF ALCALINE AIR.

If heat be applied to the caustic spirit of sal ammoniac, the volatile alcali will be expelled from the water with which it was combined, and fly off in the form of a permanently elastic vapour. This may be proved by the following elegant experiment.

Fix a slender glass tube properly bent, into a vial containing the spirit; then fill a large vial with quicksilver, which let an assistant hold inverted in a basin of the same metal. Let the tube pass through the mouth of this inverted vial: apply the flame of a candle to the vial containing the alcali, the vapour will pass through the tube into the inverted vial, and be collected in its upper part; driving the quicksilver downwards, in proportion as it accumulates. The vapour however, will not condense into a liquid, but remain in an elastic state, like common air.

Quicksilver has no action on this air, which is the reason that it is employed in the experiment. But if water be introduced, the air is presently absorbed by it; and in consequence thereof, the quicksilver rises in the vial, and nothing is to be seen but quicksilver and water. The water thus impregnated becomes *spirit of sal ammoniac.*

By impregnating water with this species of air, a caustic liquid volatile alcali may be formed, as strong as that distilled from sal ammoniac with quicklime; so that the latter preparation is nothing but water impregnated with *alcaline air.*

Other particulars of this air may be collected from the following articles.

The *fixed alcali* cannot be expelled in a permanently elastic form.

## 7.

## OF MARINE ACID AIR.

The acid of spirit of salt may be obtained separate from the water, in the form of air, in the same manner as was shewn with regard to the volatile alcali, and by the same means. It is also as readily absorbed by water.

But it is remarkable, that the marine acid in the form of air, is much stronger than in its usual state

state of combination with water. For whereas before it was the weakest, it is now the strongest of the three mineral acids; for it disengages both the nitrous and vitriolic, from their respective bases.

Water fully impregnated with this air, forms likewise a spirit of salt stronger than that obtained by distillation; and an aqua regia much more powerful than the common, may be made by a proper admixture of this air with spirit of nitre.

If this air, and the alkaline air before described, be mixed, an union is immediately formed between them; they lose their elastic, or airy form, and condense into white powder; which if collected, will scarce occupy the thousandth part of the space which the ingredients possessed before. This powder is common *sal ammoniac*.

## 8.

## VITRIOLIC ACID AIR.

The volatile vitriolic acid may be separated from the water with which it is combined, and exhibited in the form of air, like the marine acid and volatile alcali. And water impregnated with this air appears to be the same with the common aqua sulphurata.

## 9. OR

## 9.

## OF SULPHUREOUS AIR.

If an acid be added to liver of sulphur, a kind of air will arise, which may be called *sulphureous air*.

By impregnating water with this air the sulphureous waters may be imitated, in the same manner as the acidulous ones may by impregnating water with fixed air.

## 10.

## OF FIXED AIR, OR aërial ACID.

If lemon-juice be added to salt of wormwood, it is well known that an effervescence happens, by reason that there is extricated from the salt a large quantity of air.

This air, before the addition of the acid, was combined with the alcali; that is, the particles of air were attracted by those of the alcali so strongly, that they stuck firmly together. In this case therefore, the air appeared to have entirely lost its elasticity, and existed in a solid or *fixed* state, whence it came to be called *fixed air*. The term however, is equally applicable to the other kinds of air already spoken of, and for the same reasons. But as this happened to be the first in which this property was discovered, the appellation was applied to it; and has been continued

continued ever since. Experiments shew, that as much air was contained in the alcali in this fixed or coherent form, as would occupy a space some hundreds of times greater, when restored to its elasticity.

The acid has the property of freeing this air from its combination with the alcali. For the alcali attracting it still more powerfully than it does the air, unites therewith; letting go the latter ingredient, which then immediately resumes its elastic or expansive state. In its escape through the liquid, it causeth the effervescence, or bubbling, in like manner as would be occasioned by air blown through slender tubes, inserted in the bottom of the vessel.

This air may also be obtained by mixing any acid with any mild alcali, or absorbent earth. And it may likewise be expelled from the last-mentioned substances by heat: thus, quicklime is chalk, or lime-stone, deprived of its fixed air.

A large quantity of this air is extricated from vinous liquids, and other substances, while in a state of fermentation.

When vegetable and some other substances are distilled, a great quantity of fixed air is expelled merely by heat, with the water, and other volatile principles of those bodies. This part of the product had not usually been considered

sidered by chemists ; whereas now, it appears to be an important principle of bodies.

Almost half the weight of marble, for example, is fixed air. The other ingredient is calcareous earth, or quicklime. By means of this air the particles of the earth are united into that firm substance ; for when deprived of that principle, it crumbles into dust.

When we first see hartshorn distilled, we are astonished at the quantity of liquid obtained from so dry a substance. It was partly by means of the fixed air that this water, with the other principles, were united into that firm body. Vegetable, and animal substances, deprived of this air, are more disposed to putrify ; their other principles becoming more easily dissipable.

If fixed air be mixed with alkaline air, they form the mild volatile alcali. Without the fixed air, the volatile alcali cannot be obtained in a solid form.

Lime-water impregnated with this air, immediately becomes turbid ; and a white powder precipitates. Hence it is used as a test to discover the presence of this kind of air. The air uniting with the lime, renders it mild, and no longer soluble in the water.

Water imbibes this air ; and thereby becomes artificial *Pyrmont water*. Water, thus impregnated,

nated, is capable of dissolving iron, camphire, and some other substances ; which it could not do before.

Fixed air has been successfully applied to medical purposes as an antisепtic ; and in some other intentions. For tho' it will not serve for respiration, it is not hurtful when taken into the system. On the contrary, experience proves it to be very salutary.

Fixed air acts on alcalis as an acid of the weakest kind, and thence is justly called by the ingenious Mr. Bewly, and Professor Bergman, an acid. Hence mild alcalis may be considered as a kind of neutral salts.

For many other curious particulars, respecting the different kinds of air, the reader is referred to Dr. Priestley's justly admired publications on these subjects\*. To that philosopher the world is indebted for almost the whole of what is known concerning them.

These are the principal substances, yet known, capable of existing in a permanently elastic state in the common temperature of the atmosphere. But it may be observed, that many other bodies are capable of being turned into air by a sufficient heat. Thus, the bubbles of boiling water  
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\* The abbe Fontana affirms that vegetable acids, without exception, are resolvable into fixed air ; and thence concludes that fixed air constitutes the very essence of those acids.

are water converted into an elastic fluid, which may therefore be called *aqueous air*. But this, when the heat sufficiently abates, loses its elastic state, and returns into the form of water. The like may be observed of spirit of wine, oil, quicksilver, &c. In the Introduction, it was observed, that bodies may exist in three different states; a solid, fluid, and an elastic one; but that bodies of various kinds require different degrees of heat for these purposes. Thus, an heat less than the lowest degree that we can produce, is sufficient for the formation of common air. Water requires a greater heat for that purpose than the usual temperature of the atmosphere; and earths cannot be made so by the most violent of our fires.

## C H A P T E R VI.

OF PHLOGISTON, AND ITS COMBINATIONS.

**T**HIS principle seems to be of so subtle a nature that it cannot, like water, be obtained in a separate coherent form ; nor like air, be confined in a vessel.

But tho' we cannot obtain phlogiston in a separate state, yet we can transfer it from one body to another, which is sufficient for chemical purposes. Thus, if powdered charcoal be mixed with the calx of lead, and placed in a proper vessel over a fire sufficiently strong, the phlogiston will quit the charcoal, to combine with the calx, by which it is more powerfully attracted ; and which will thereby be formed into lead.

Thus again, phosphorous is a combination of phlogiston with the phosphoric acid. But if the phosphorus be exposed to the air, its phlogiston will leave the acid, and combine with the air by which it is more strongly attracted ; and the new combination is *phlogisticated air*.

The fusibility of bodies is promoted by their combination with this principle. Thus, minium is very difficult of fusion ; but lead melts with much less heat. It also causeth bodies to be more ductile, or malleable than before.

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I shall have occasion to speak of this principle in future; and at present shall only consider those bodies of which it forms a constituent part.

## I.

## OF METALS.

Metals are divided into perfect, imperfect, and semi-metals. The perfect metals are gold, silver, and platina. They are so termed because they remain unaltered in the fire. The only effect that the heat of our furnaces has on them is to render them fluid: when the heat is removed they return to their solid state without having suffered any change either in their properties or weight.

The imperfect metals are copper, iron, lead, tin, and quicksilver. They differ from the perfect metals in being calcinable by heat; or of being changed thereby from metals, into mere calces, or earths.

The semi-metals are zinc, regulus of antimony, nickel, &c.

In the calcination of metals, one of the ingredients, the *phlogiston*, is taken from them by the air; in lieu of which, they usually attract fixed air, or some other, from the atmosphere; and hence the calx is found to be heavier than the metal before calcination.

Metals

Metals are also converted into calces by those acids which are capable of dissolving them. For their phlogiston escapes, and only the calces remain with the acids.

The calces of metals are, like other earths, convertible into glaiss. But this is not the case with the metals themselves. Metals are the most ponderous of all known bodies.

The phlogiston of all metals is exactly the same; and therefore the difference in them is owing entirely to the nature of their calces: Those differences are sufficient to distinguish the metals from each other. Thus, phlogiston, united with the calx of

#### GOLD,

Forms a metal whose specific gravity is nineteen times greater than that of water; and the only acid in which it can be dissolved, is aqua regia. Its colour is yellow, and it is unalterable by the heat of our furnaces. With the calx of

#### PLATINA,

It composes a metal which resembles gold in its specific gravity, perfectness, and solubility in aqua regia, but differs from it, in being infusible by the fires of our furnaces; whereas gold is fusible. With the calx of

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#### SILVER,

## SILVER,

It forms a metal, which, like gold, is indestructible by the heat of our fires, but has much less specific gravity, and is soluble in the nitrous acid. With the calx of

## COPPER,

It forms a metal calcinable by heat; of a reddish colour; not fusible but in a great heat, and soluble in all the acids. With calx of

## LEAD,

A metal is formed by it, fusible in a moderate heat, and not difficultly calcinable. It is the softest of all metals, and also the heaviest, excepting gold, platina, and quicksilver. With calx of

## IRON,

It forms a metal capable of being attracted by the load-stone; which requires the most intense heat to fuse it; is soluble in all acids and alcalis; is the least malleable, and most elastic of all metals; and which rusts on exposure to moist air. With calx of

## TIN,

It forms a metal the lightest of all others, and the most fusible except mercury; the softest next to lead; and which when pure, crackles on being bent. With calx of

## MERCURY;

## MERCURY,

It forms a metal the heaviest of all the imperfect ones; volatile by heat; and which remains fluid in the common temperature of the atmosphere. With calx of

## ZINC,

A semi-metal is composed soluble in all acids, and which may be sublimed in the form of flowers. Its colour is a blueish white, and is commonly named *tutenag*. With calx of

## ANTIMONY,

It forms a semi-metal, soluble in aqua regia, but not in other acids, or difficultly and imperfectly. It sublimes into flowers ; and when combined with sulphur forms *antimony*.

The other semi-metals are also formed of phlogiston, and the respective calces. But different calces require different proportions of that principle, in order to their metallization.

II.

## OF SULPHURS.

Phlogiston properly combined with the vitriolic acid, becomes

I.

## BRIMSTONE,

Or common sulphur. If vitriolated tartar, Glauber's salt, or other substance containing  $\text{F}_2$  vitriolic

vitriolic acid, be fused with charcoal, the acid of the former and the phlogiston of the latter, will unite and form sulphur.

This substance easily melts. It is neither soluble in acids, water, nor spirit of wine; but may be united with oils, and some of the metals; and also with alkaline salts and quicklime, forming *hepar sulphuris*.

It is kindled with less heat than almost any other inflammable substance; burns with a blue flame, and suffocating smell. In this process its phlogiston is attracted by the air, leaving the acid behind in the form of vapour; and which is the cause of the smell just mentioned. This again shews that phlogiston and the vitriolic acid are the principles of which it is composed.

The proportion of acid to that of the phlogiston in this compound is said to be so great, that an ounce of sulphur contains above seven drachms of vitriolic acid, several times stronger than the best oil of vitriol that we can procure. This may appear surprising, when it is considered that sulphur is insipid to the taste, whereas the vitriolic acid is one of the most caustic substances in nature. The reason of this will be shewn in a future chapter.

## 2.

## PHOSPHORUS.

It is composed of phlogiston and the phosphoric acid, in the same manner as brimstone is composed of phlogiston and the vitriolic acid, and therefore must be considered as a *sulphur*.

Its principles seem to be less strongly united than those of brimstone; for the latter substance requires to be heated in order to make it inflame; but phosphorus parts with its phlogiston to air, without the assistance of heat; and hence it is that it kindles on being exposed to the air.

After combustion, its acid remains behind in a solid state; in which respect likewise it differs from brimstone. A smell of garlic is perceived while it is burning.

Nitrous air may also be considered as a *nitrous sulphur*.

## 3.

## OF COAL.

By *coal* is meant any oily substance burnt to blackness: as the coal of wood, charcoal, and the like. It may be considered as a combination of phlogiston, with animal or vegetable

earth. If it be deprived of the former ingredient by combustion, the earth remains behind. Coal also contains a great quantity of air in a fixed state.

## 4.

## OF OILS.

Oil, simply considered, is probably a combination of phlogiston, with an acid, earth, and water.

Oils are inflammable, and burn with a soot, leaving also a coaly matter behind, unless it be carried off in the vapour. They are not usually miscible in water; but either swim above it, or sink to the bottom, according to their specific gravity. The substances with which they are accidentally combined make a considerable variety in them. And, as their properties are different, we shall, as in the case of earths, consider them as distinct substances.

## I.

## EXPRESSED VEGETABLE OILS,

As oils of almonds, olives, &c. When pure they have neither taste nor smell, and are soft and bland; they neither mix with water, nor spirit of wine.

With

With caustic fixed alkaline salts they form common soap; they dissolve sulphur, and calx of lead; and unite with essential oils. They also swim in water.

## 2.

## ESSENTIAL VEGETABLE OILS,

Or those obtained by distilling vegetables; as lavender-flowers, caraway-seeds, &c. with water.

They dissolve in spirit of wine, and produce cold thereby. They unite with water by distillation; and hence the smell and other properties of distilled simple waters. They have the smell and taste of the subjects from which they were drawn.

With concentrated nitrous acid, they inflame; especially if oil of vitriol be added.

They form volatile *soaps* with the volatile, and those called *philosophical* with fixed alcalis. When they are in a dry or solid state, they are called

## 3.

## RESINS.

Thus, resin of jalap, of guaiacum, &c. may be considered in this light; as may also camphire. They agree with essential oils, in their

being soluble in spirit of wine, not in water ; and in several other properties.

## 4.

## ANIMAL FATS,

Their properties are very similar to those of expressed vegetable oils. They differ from them chiefly in being usually in a solid state; whereas the others are most commonly fluid.

There are other diversities in oils; as the empyreumatic oils of animals and vegetables; arising from their being partly decomposed by the fire; fossil oils; and the substances resin, wax, &c. But for accounts of these, authors on the *materia medica*, and practical chemistry, may be consulted, a particular enumeration of them not being necessary to a work of this nature.

## 5.

## VINOUS SPIRIT.

It seems to be composed of acid, phlogiston, and water. It burns without foot, or coal.

It mixes with water. It dissolves essential, but not expressed oils; resins are also dissolved by it.

It

It is easily inflammable ; and its capacity for containing fire is greater than that of oils. It also burns with a weaker flame.

It coagulates animal fluids ; is very volatile ; and, excepting æther, is one of the lightest of liquids.

## 6.

### ETHER.

It is produced by distilling pure vinous spirit with a concentrated acid.

It is the lightest of all known liquids. It neither unites with vinous spirit, acid, nor alcali, but dissolves essential oils and resins. It unites, in a very small proportion, with water.

Besides the substances already mentioned, phlogiston enters more or less into the composition of all bodies, though in less proportion, or else in a less obvious manner than in those specified. But these are sufficient to shew the great importance of this principle, and in some measure its nature. For it is absolutely necessary to the formation of inflammable matters ; and of course to vegetable, animal, and other bodies,

dies, into the composition of which inflammable substances are known to enter. It also seems necessary to the formation of *air*, and to many other important purposes in nature, which it is not necessary at present to consider.

## C H A P T E R VII.

## O F F I R E.

**F**IRE is that subtle principle which causeth heat. As heat is the most obvious effect of fire, I shall first discourse of it.

If the heat or warmth of any substance be greater than that of the part of an animal body to which it is applied, it causeth the sensation of heat in that part ; if contrariwise, cold ; but if the heats be equal, neither of these sensations are caused. Thus, if water be hotter than the hand, it feels warm ; if colder, cold ; but if it be of an equal heat with the hand, it neither feels hot nor cold. The hand however is no certain measure of heat ; for if one hand be hotter than the other, the same water may at the same time feel hot to one hand, and cold to the other. And, at different times, water of the same warmth may feel hot and cold even to the same hand.

Philosophers therefore have another, and more accurate method of measuring heat, which is by the thermometer. When a body is hotter, the fluid in the thermometer applied to it rises higher ; and when colder, the fluid sinks lower,

and

and a graduated scale is affixed to the tube to mark the degrees. A body therefore is not said to be hot, or cold; but only more or less hot\*. Ice, for example, has a less degree of heat than boiling water. The heat of a body is also called its *temperature*.

The most general effect of heat on bodies, is to expand them into greater dimensions: there is not a body yet known but what is thus affected by heat. If a small quantity of air be contained in a bladder, the application of heat will expand it into so great a bulk, that the bladder will be compleatly distended. If spirit of wine be put into a long slender tube, and then made hot, it will very considerably expand; and if a rod of iron, which can just enter a ring when cold, be made red hot, it cannot then enter that ring, by reason that it is expanded in bulk by heat: All bodies therefore are expanded by heat; and the only difference is, that some are more expanded than others, for reasons which will appear in the sequel.

On

\* Besides, though they do not appear hot to the sense, are in reality very considerably so. It has been found, for example, that they are capable of being cooled above 200 degrees below the usual heat of the hand. If therefore the usual heat of the hand were at that point, and a body which does not now feel warm were applied to it, the heat would be equal to that which is now felt on putting the hand into boiling water. A very considerable quantity of fire therefore is contained in bodies, when at the common temperature of the atmosphere.

On this principle the thermometer is formed. A glass tube is made, with a bulb at the bottom, capable of holding a sufficient quantity of quicksilver, or spirit of wine. When heat is applied, the fluid in the bulb is expanded, and for want of room makes its way up into the tube, so that the surface rises higher. When a less degree of heat is applied, the fluid in the bulb is contracted, and therefore part of that which is in the tube will sink down into the bulb, its surface becoming lower than before. The graduated scale indicates the difference, and therefore measures the degree of heat.

If bodies are heated less than a certain degree, they are solid ; if they are heated beyond that, they are fluid ; and if they are heated beyond a certain greater degree, they are rendered elastic, or turned into vapour or air, as was mentioned before. Water, for example, when it has only 32 degrees of heat, by Farenheit's thermometer, is solid ; and it is solid in all degrees of heat below 32. When the heat is greater, it melts, or becomes fluid. And when the heat is boiling and beyond, it loses its fluid form and is turned into vapour, or else rendered elastic like air. The like happens to quicksilver, with this difference, that quicksilver loses its solid form in a less degree of heat than water ; and yet does not become elastic, but with a greater heat. Zinc does not become

fluid.

fluid, but with an heat greater than that which would turn water into vapour; yet there is a less number of degrees between its solid and elastic state, than in water. Gold does not become fluid but with a very intense heat; and the strongest of our fires cannot turn it into vapour; and some earths cannot even be rendered fluid with the greatest heat that our furnaces can give. On the other hand, spirit of wine cannot be rendered solid; and air cannot even be brought to a fluid state, by the most intense cold that we have yet been able to produce. Yet a solid, fluid, and elastic state, are with reason concluded to be proper to all those bodies, provided they were in the degrees of heat requisite for these purposes. The only difference between bodies in this respect is, that no two of them have their solid, fluid, and elastic points at the same degrees of heat.

When bodies which differ in these respects are mixed together, they may therefore be separated from each other by proper applications of heat, provided their particles do not too strongly cohere; but of this, and of the other chemical uses of heat, more will be said on a future occasion.

Fire has a tendency to diffuse itself over all bodies, till they are of an equal degree of heat or warmth; and this equality of heat is called the

the *common temperature*. Thus, if a red hot bullet be placed upon three others which are cold, the former will be continually losing heat, and the latter gaining; but all of them will be continually losing heat to the bodies around, till they are all of the same temperature.

If a pound of hot water be mixed with a pound of cold, the heat of the water after mixture, will be in the mean between the heats of the two portions before the mixture; the cold water will be heated half way to that of the hot, and the hot water will be cooled half-way to the temperature of the cold.

If a pound of hot water however, be mixed with a pound of cold linseed oil, the heat of the mixture will be greater than the mean of their two heats before mixture; and if, on the contrary, the water be cold, and the oil hot, the heat will be less than that mean. This is a very curious difference; and the cause of it may be understood from what follows.

If a pound of water be placed in a vessel in a certain degree of heat, and another pound in a similar vessel in the same heat, the heats which they gain or lose in the same times will be equal.

But if in one of the vessels be a pound of water, and in the other a pound of linseed oil,  
the

the oil will acquire a greater degree of heat, in a given time, than the water; and the like difference is observable in their cooling. In other words, the same quantity of fire will heat the oil more than the water; and the same quantity of fire taken from the oil, and from the water, will cool the water less than the oil.

Half the fire contained in the hot water therefore, heated the oil more than it cooled the water, and the heat after the mixture was more than the mean. On the contrary, half the fire contained in the hot oil heated the water less than it cooled the oil, and of course the heat after mixture was less than the mean. And, as in the cases of expansion, &c. so in this, there are perhaps no two substances exactly alike in this respect.

Different bodies therefore have different powers, or capacities for containing fire; and hence when they are at a common temperature, or equally hot to the sense and the thermometer, the proportions of that principle which they contain, are unequal. The capacity of linseed oil, for example, is less than that of water; and therefore when equally hot to the sense, and the thermometer, contains less fire. An equal proportion of that principle added to, or subtracted from, the water and the oil, ought in

in course to affect the temperature of the latter, more than the former.

The ingenious Dr. Irvine (to whom, in conjunction with the celebrated Dr. Black, we are indebted for this doctrine) has discovered a method by which the capacities of bodies may be determined by experiment. If, for example, I would know the proportion of the capacities of two liquids, I heat one of them, and pour it on an equal weight of the other while cold, having previously noticed the difference of their temperatures. If the capacities are equal, the heat of the mixture will be in the mean between the temperature of the two liquids before mixture; as was before observed to happen, when water is mixed with water. But if their capacities are unequal, the heat of the mixture will vary from the mean in proportion to that difference, as was observed to be the case on mixing water with linseed oil; the capacities of which are to one another very nearly in the proportion of 2 to 1. To these experiments however, it is necessary that the substances should have no chemical action on each other: that is, they should produce neither heat nor cold, when mixed together at like temperatures.

Not only different bodies have different capacities, but even that of the same body is va-

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riable, according to the state which it happens to be in. When water freezes, its capacity becomes *less* than it was during the fluid state; and on the contrary *greater*, when it is turned into vapour. The same rule holds good with other substances.

When the capacity of a body happens to be altered, it is evident that its temperature will be affected in proportion thereto. Thus, if the capacity be suddenly increased, the body will become colder than before; and if diminished, hotter. Accordingly we find, that heat is generated by the congelation of fluids; and cold, by their evaporation. Cold is a consequence of the transition from a solid to a fluid state; and heat, of the condensation of vapour.

When water is mixed with oil of vitriol, a great degree of heat is produced. The capacity of the mixture becomes less than the sum of the capacities of the ingredients before mixture; of course the fire which they contained, must occasion the temperature of the mixture to be higher.

On the contrary, when snow is mixed with spirit of nitre, the capacity of the solution becomes greater than the sum of the capacities of the ingredients before mixture. The quantity of fire which they contained becoming now too little;

little, the temperature must sink in proportion thereto. The like may be observed of the other instances of heat and cold generated by chemical mixtures.

The difference of the capacities of bodies may depend on different arrangements of their particles, or on other circumstances, with which we are not yet properly acquainted. But by observations related in a book \*, published by the author of this work, but more particularly by the experiments of the ingenious Dr. Crawford, it appears that, in some cases, *phlogiston* causeth this difference in bodies. Bodies which are freest from that principle have (at least in many instances) their capacities greater than those which contain it in greater proportion. Thus oil contains more phlogiston than water, and its capacity is found to be less. The like may be observed of metals, and their calces; of sulphur, and the vitriolic acid ; and in other cases of phlogisticated and dephlogisticated bodies.

Hence if the phlogiston be supposed to be suddenly taken from oil, its capacity will be increased. The quantity of fire which it contained will no longer be sufficient to keep it at the same temperature as before. It will therefore

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fore

\* Philosophical Observations.

fore become colder ; and of course will imbibe fire from the substances around, till it returns to an equal temperature with those substances.

On the contrary, if the phlogiston be supposed to be suddenly restored, the capacity will be lessened. The fire which it contains, will raise it to an higher temperature than before ; and therefore it will communicate heat to the surrounding bodies, till an equality of temperature between them again obtains.

The same quantity of phlogiston combined with different bodies, affects their capacities in different proportions. Thus, if the phlogiston of *oil* be transferred to *air*, the capacity of the latter will be more diminished than that of the former is increased. The heat generated by the combination therefore, will be greater than the cold produced by the decomposition ; and on this principle we account for the heat in the combustion of oil, and other substances.

The elasticity of air depends on heat. For if the heat be increased, the elasticity is increased. If the heat is diminished, so is likewise the elasticity. If therefore air were sufficiently deprived of heat, its particles would probably become coherent, like those of water, and other substances.

The

The effect of fire on the particles of bodies, therefore, is to give them a repulsive power. Thus, if two or more particles be in contact, cohering with each other, and heat be applied, the repulsive force which they acquire in consequence thereof, will oblige them to quit each other. Hence the expansion of bodies by heat. The particles while within their spheres of cohesion will resist the action of heat more, as their attractive or cohering forces are stronger. But when the heat becomes so great as to urge them beyond those spheres, they will become elastic like air; the repulsive force which they acquire from the heat, overpowering that of their attraction. This is the reason that particles are separated from each other, or *volatilized* by heat. See also what was said of the three states of bodies in the former part of this chapter\*. But

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\* I once formed a supposition that the particles of bodies had two spheres of attraction or cohesion, one within the other: the inner and stronger one, I called the *solid* cohering force; the outer and weaker, the *fluid*; that while the particles were mutually within the former, the body which they composed was solid, or hard; and that when they were forced into the latter, it became fluid; that from the structure or density of these spheres, the capacity of the body was necessarily less when the particles were mutually within the solid spheres, than when forced into their fluid ones, and least of all when rendered elastic. That the diameters of these spheres, in different kinds of particles, might be in different proportions to each other, as might also their forces, and the ratios of these forces. By varying these suppositions, many of the phenomena relating to these subjects seemed to be pretty naturally accounted for. But this is a mere hypothesis.

independently of their cohering forces, the particles of bodies seem to be some more, and others less, capable of being made repulsive by heat. Thus different kinds of air are capable of being differently expanded by equal degrees of heat, though the particles in this case are without the spheres of their cohering forces.

The uses and effects of fire, or heat, in chemical operations, will be considered in the next section.

SECTION

## S E C T I O N II.

**H**AVING given an account of such chemical substances and agents as required explanation, we may proceed to the subject of chemical operations : and it will be most proper and natural to consider those first which depend merely on heat.

It must however be remembered, that I do not make it my business in this work to treat of the *practical* part of chemistry ; the *philosophy* of that science was all that I proposed ; and even no more of that than might be sufficient to enable the reader to enter, in a **MORE GENERAL MANNER**, into these useful and entertaining studies.

## C H A P T E R I.

## O F V O L A T I L I Z A T I O N .

**B**Y this term we understand that part of chemistry, which treats of the separation of volatile from fixed substances ; that is, the decomposition of bodies, by heat alone.

If a volatile substance, as water, be combined with a fixed one, suppose fixed alcali, they may

be separated by putting the mixture into a proper distilling vessel, and applying a sufficient heat. For the water will be raised into vapour and distil into the receiver, leaving the alcali at the bottom.

A greater heat however will be required than if the water had been distilled alone, because the water is attracted by the salt; and the heat in these cases is required to be greater according as the attraction is stronger, so as to overcome that attraction.

You will find by the 3d chapter of the former section, that green vitriol is a compound of vitriolic acid and iron. But a proper degree of heat forces over the acid (together with some water, which the vitriol also contains) in the form of spirit of vitriol, the iron remaining in the form of colcothar behind.

Hartshorn is a combination of animal earth, volatile alcali, oil, water, fixed air, &c. Heat forces over all the volatile ingredients, leaving the earth behind.

So guaiacum wood is a combination of vegetable earth, salt, acid, water, air, and oil. By the application of a sufficient degree of heat, the latter ingredients being volatile, are separated in vapours; the earth with the fixed alkaline salt remaining behind. The like may be observed

observed of other animal and vegetable, and of many of the mineral substances also.

In cases however where the attraction of the ingredients is very strong, this decomposition cannot be effected by our fires. For example, vitriolated tartar is a combination of the vitriolic acid with fixed alcali. The acid, though volatile, cannot be separated from the alcali by the utmost force of our furnaces, by reason that it is so strongly attracted by the alcali. The like may be observed of some other substances.

In the instances last mentioned, the power of the fixed ingredient fixes also the volatile one. There are others, in which the volatile one volatilizes also the fixed. Thus, sedative salt of Homberg is fixed. But if it be combined with water, the water carries it up with itself in vapour. Iron is, in like manner, volatilized by sal ammoniac.

If substances of different volatility be mixed together, and have but little or no attraction for each other, the most volatile may be driven over in distillation; leaving the other, or others, behind; provided only such a degree of heat be applied, as is just sufficient to raise the former in vapors, but not the latter. Thus, if water and spirit of wine be mixed together, both which are

are volatile, the spirit will rise first, the water not till the heat becomes greater. In like manner, water may be raised from spirit of vitriol ; the acid, being more fixed, remaining concentrated behind. So volatile alcali may be separated from water ; essential oils from those of a more fixed nature : And hence also, the matters obtained by distilling hartshorn, guaiacum, and other substances, may be separated from one another, as you find by their processes in chemical books.

But in cases where the principles strongly attract each other, they will not be separated, but both rise together in their combined state. Thus, the marine acid, and volatile alcali, are both volatile ; but the latter more so than the former. Yet heat does not separate them, as in the cases last mentioned, but they both rise together in the form of sal ammoniac. So sulphur and quicksilver rise together in the form of cinnabar ; and the like happens in many other instances.

If in a substance to be distilled, oil and water are contained, they may both be driven over into the receiver ; and as they will not mix, the oil will either float at top, or sink to the bottom, according as its specific gravity is greater or less ; and therefore they may be separated by filtration, or other *mechanical methods contrived for*

for that purpose. Hence essential oils are obtained by distillation. And the like may be observed of other matters, which will not mix; as of quicksilver and water, water and phosphorus, &c. Hence though the matters may be of different volatility, yet the necessity of the mode of separating them by heat, is, in these cases, superseded.

It should be observed, that *air* has some share in the business of volatilization. Thus, water placed *in vacuo*, evaporates with much greater difficulty than when the vessel contains air, or when in open exposure to that element. The air in this case acts as a *menstruum*, or *solvent*. See also what was said on this subject, in the chapter on Air.

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## O F M E N S T R U A.

ONE of the most useful branches of chemistry depends on the doctrine of menstrua. The extracting of tinctures, decoctions and infusions depend on this principle.

In order to effect solution, one of the substances at least must be fluid. The fluid substance is called the solvent or menstruum.

There are some bodies which dissolve entirely in certain menstrua. Thus sugar wholly dissolves in water; camphire is totally dissolved by spirit of wine; wax dissolves entirely in oil; and quicksilver in spirit of nitre. In many instances, these solutions may be made in the usual temperature of the atmosphere. Others require heat to dissolve them; but in all these cases, agitation greatly facilitates the solution, as by it the unsaturated parts of the menstruum are applied to the substance to be dissolved. This operation depends on the principle of attraction, already spoken of. Thus spirit of wine dissolves camphire, because there is a mutual attraction between the particles of these ingredients. But camphire is not dissolvable by water, for want of

of such mutual attraction. Spirit of wine therefore is a menstruum for camphire, water not.

In most cases, however, only part of the principles of which a body is composed are soluble in any one menstruum; for example, aloes consists of two different substances or principles, a resin and a gum; spirit of wine dissolves resinous substances, but will not touch gummy ones. If, therefore, it be required to extract the resin from the aloes, it must be digested in spirit of wine. The resin will be dissolved, the gum remaining behind. But gummy substances are dissolved by water. Hence, if it be required to extract the gummy part from the aloes, water must be used: when therefore tinctures are extracted from substances with pure spirit of wine, it is with a view of obtaining their more oily or resinous parts. Hence, the tinctures of assafœtida, guaiacum, balsam of Tolu, and the like.

On the contrary, when water is employed, whether in the way of infusion or decoction, it is with design to extract the saline, gummy, gelatinous and mucilaginous parts; of all which water is a solvent.

By treating any substance therefore, first with spirit of wine, and afterwards with water, or first with water, and afterwards with spirit of wine, we extract from it both its resinous and saline  
and

and gummy parts. If the substance contains no other than these (as is the case with aloes, assafoetida, &c.) it will be totally dissolved. But if it also contains earthy, or other matters, not soluble in those menstrua, those parts will remain behind.

If, however, water and spirit of wine be mixed together, they will not always dissolve those substances which are wholly soluble by them when applied successively, because they then weaken each other's attractive or solvent virtues. Thus, water and spirit of wine will not dissolve aloes, assafoetida, &c. The tincture, however, which is extracted by this mixture, partakes both of gummy and saline, and of resinous parts, though in a less degree than when employed separate.

For the same reason, if the tinctures drawn by those menstrua separately, be mixed together, they will not incorporate into a clear tincture; but because the forces of the menstrua are mutually weakened, they each let go part of what it before retained; the mixture in course becomes muddy, and a precipitation ensues.

Heat increases the dissolving power of menstrua, and in some cases gives that power where it did not before appear. Hence many spirituous tinctures

tinctures are directed to be drawn with heat; and watery ones are most generally made either with hot water, or by actual boiling.

In many cases, the part of the substance dissolved carries with it into the tincture, infusion, or decoction, many particles of the substance, not naturally soluble in that menstruum. Thus, wine extracts part of the resin from opium, which it lets go again in time. Water draws out not only the saline and gummy, but also great part of the resinous, and even woody parts from bark; but lets them fall to the bottom, in great measure, after standing a sufficient time. Thus also water dissolves gum ammoniac, assafœtida, &c. into milky, or otherwise turbid liquors. The turbidness shews the tincture to be imperfect; and ariseth from the resinous parts still held by the others, which the water dissolves, and which, therefore, is rather a mixture than a tincture, and will, in time, separate. Oil is in like manner mixed imperfectly with water, by means of an alcali; the water dissolving the alcali, and that still retaining the oil. Hence the turbidness or milky appearance of that mixture.

In common distillation, the water used for distilling simple waters, and the spirit of wine employed in the distillation of spirituous ones, act also as menstrua. In the former case, the saline parts of the vegetable substance are dissolved

solved in, and carried over by, the vapour of the water: in the latter, the resinous, or those depending on the essential oil, are in like manner extracted and carried over by the vinous spirit. These therefore may also be considered in the light of infusions or decoctions, and tinctures; the only material difference being, that in ordinary decoctions and tinctures, the more fixed parts of the substance are also retained by the menstruum; in distillation, only the volatile parts.

Any other fluid that acts on, and dissolves the whole, or any part of a substance, may also be considered as a menstruum. Thus, oils are menstrua to many substances which water and spirit of wine will not touch. Acids are menstrua to metals, earths, &c. Air is a menstruum to water, and other matters; by which means their volatilization is also facilitated, as hath been observed. Substances reduced to vapour, or air, even act more powerfully than in a fluid form. Thus, spirit of salt and spirit of wine will not form ether, unless mixed together in a vapoury state; and there are other instances of a like nature.

From hence it appears, that the decomposition of bodies by means of menstrua, forms an extensive branch of chemistry; and it has this excellence, that the virtues of animal and vegetable

table substances may be extracted, at least by water and spirit of wine, without alteration, which is not commonly the case with operations by the retort. For example, by the retort all vegetables yield nearly the same principles, viz. oil, an acid, water, fixed alcali, and earth; and the like may be observed of the distillation of animal substances by the same method. But by means of water, and spirit of wine, as above, their respective virtues may be obtained unaltered. The like holds good with extracts, as will be seen in the next chapter.

## C H A P T E R III.

## O F E X T R A C T S.

**T**HE doctrine of extracts, according to the strict sense of the word, depends on the two preceding heads of volatilization and menstrua.

Extracts may be divided into spirituous, watery, &c. according to the nature of the menstruum employed, and of the extract to be made.

A resinous extract is drawn by means of vinous spirit; for example, if I would extract the resinous part of aloes, bark, or any other substance, I bruise the ingredient and infuse it in rectified spirit, with a proper degree of heat, agreeable to what was delivered in the last chapter: I then decant, or filter the liquid; and as the spirit is more volatile than the resin, it may be raised from it by evaporation, or by distillation, as may be understood from what was delivered in the 9th chapter; the resin remaining at the bottom.

If I would extract the saline or gummy matter from a substance, I boil or infuse it in water, and afterwards distil or evaporate the water by a proper degree of heat; the extract, being less volatile, remaining behind.

As

As spirit of wine evaporates with less heat than water, extracts made by the former contain more of the volatile parts of the substance, than those made by the latter. For though you may observe, that in an extract or resin only the more fixed parts of the substance can be retained, the volatile ones flying off in evaporation; yet the more of those volatile parts that can be retained, the more of the virtue of the substance will the medicine contain. Hence the flower the evaporation proceeds, the better will the extract be.

In order that it may contain as much as possible of the virtue of a substance, the gummy and saline, and the resinous parts are, in some cases, directed to be severally drawn with water, and spirit of wine. Thus, in some recipes, a tincture is directed to be drawn from bark with spirit of wine, in order to extract the resin, and the bark to be afterwards boiled in water, to get out the other principles. These tinctures, or rather the extracts made from them when nearly reduced, are then directed to be mixed together; such an extract therefore contains both the resinous and saline-mucilaginous principles; or, in other words, the whole virtue of the bark.

By proper management an extract similar to the above may be drawn with water alone. Thus, a small quantity of water is added to opium, only sufficient to make it into a pulp; the

gummy and saline parts are hereby sufficiently dissolved. At the same time the resin is melted by the heat, and as the mixture is thick, does not separate, but is entangled by and blended with the other parts, so as to pass the strainer together. A due degree of heat afterwards reduces it to its proper consistence.

Any liquid substance, vegetable juice, &c. properly evaporated, may also be called an extract. Thus the juice of elder-berries evaporated, called rob of elder, is an extract. Sugar of lead, extracted from ceruse, or litharge by vinegar, and then evaporated, is an extract; and so of others.

## CHAPTER IV.

## OF FERMENTATION.

**V**EGETABLE and animal substances only are subject to this process. There are several stages of it; all of which vegetable, but not animal substances, may undergo.

By fermentation, the particles of the compound suffer a new arrangement; so that the properties of the substance become different from what they were before.

If a vegetable juice (of grapes, for example) be fermented, it will yield on distillation, inflammable spirit, which the *must* did not yield before fermentation. This is called the *vinous* fermentation.

If the same liquid be farther fermented, it yields vinegar, which could not be obtained from the liquid before, either in its original or vinous state. This therefore is called the *acetous* fermentation.

The third stage of fermentation, is *putrefaction*; by which the substance is converted first into a mucilage, and afterwards into calcareous earth, marine, and other acids, and volatile alcali; which escaping with a portion of

oily matter, occasions the disagreeable smell arising from putrifying substances.

Animal substances can only pass through the latter stage, and therefore have probably already undergone the former.

A quantity of *fixed* air escapes from the fermenting substances during their first stages; but in putrefaction, *inflammable* air also arises. In all fermentations therefore, not only new arrangements of the particles take place, but parts of them are separated, and fly off.

## S E C T I O N

## S E C T I O N III.

BEFORE we enter on the subject of this section, it may not be improper to premise the following, taken from the writings of the ingenious Dr. Fordyce; to which we are also indebted for the chapter on fermentation.

COMBINATION IS OF TWO KINDS; MECHANICAL  
AND CHEMICAL.

Mechanical combination is also of two kinds. First, *Mixture*; when the particles of one of the bodies attract one another stronger than they do those of the other. In this case, if they be both fluid, the one which is least in quantity, is broke down into spheres; as oil is when mixed with water.

Secondly, *Diffusion*; when the particles of one of the bodies attract those of the other. In this case they intermix equally. Thus, solution of blue vitriol mixes uniformly with water.

In mechanical combination, the properties of the elements remain exactly the same as before the mixture; and the properties of the compound depend on them.

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When the bodies are of different specific gravity, they remain mixed from friction; and the attraction of the particles of the one in the largest quantity, to one another.

But in chemical combination, the substances unite by an attraction which takes place between themselves, without any external power.

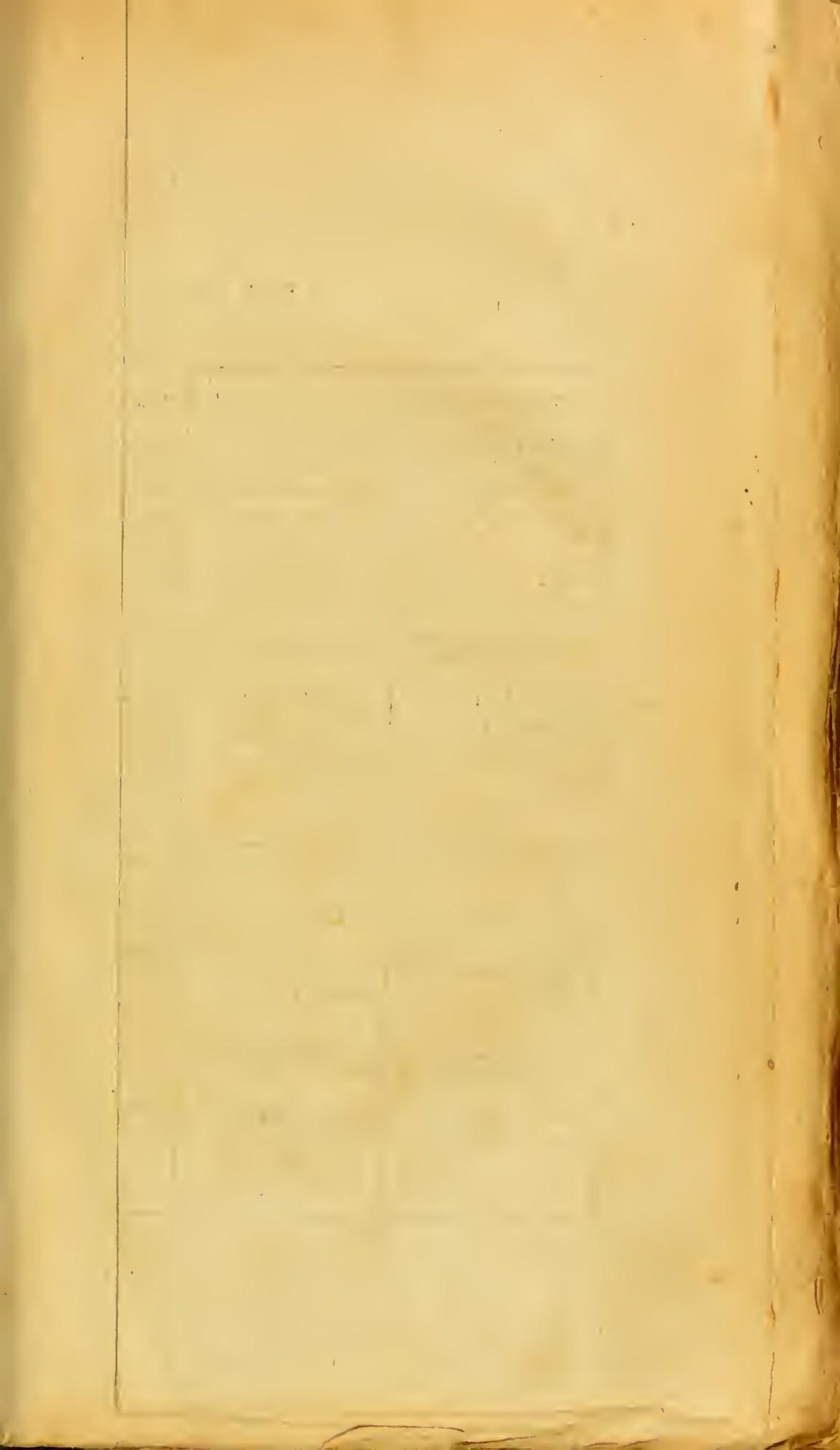
A particle of each element unite together so as to form but one particle, considered mechanically. Thus nitrous acid, and fixed vegetable alcali, form nitre; which is to be considered mechanically as one simple substance.

The properties of the compound do not depend on the properties of the elements.

No mechanical power can separate the substances so combined.

A compound may become an element. Thus, vitriolic acid and phlogiston form sulphur. But sulphur with fixed alcali, forms hepar sulphuris; so that in this case the sulphur, though a compound of two other principles, is only an element of the hepar.

Elements remain combined from the attraction which takes place between them.



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E L E C T I V E   A T T R A C T I O N S .

To front page 105.

1. VITRIOLIC ACID.		2. NITROUS ACID.		3. MARINE ACID.		4. ACETOUS ACID.	
Phlogiston Fixed Alcali Volatile Alcali Magnesia Zinc Iron Copper Water	Sulphur Tart. Vitriolat. Sal Ammon. Vitriolic Sal Cath. Amar. Vitriol Alb. —Virid. —Cærul. Spirit. Vitrioli	Phlogiston Fixed Alcali Volatile Alcali Iron Copper Silver Water	Nitrous Air Nitre Sal Ammon. Nitros Lunar Caustic Sp. Nitr <i>i</i>	Fixed Fossil Alcali Calcareous Earth Volatile Alcali Regulus of Antimony Silver Mercury Lead Water	Common Salt Liquid shell Sal Ammoniac Butter of Antimony Luna Cornua Merc. Corros. Subl. Plumbum Cornuum Spirit of Salt	Fixed Alcali Volatile Alcali Magnesia Lead Copper Water	Tart. Solub. Spirit Minderer Sacc. Saturn. Crystal. Veneris Vinegar
5. FIXED VEGETABLE ALCALI.		6. FIXED FOSSIL ALCALI.		7. VOLATILE ALCALI.		8. CALCAREOUS EARTH.	
Vitriolic Acid Nitrous Acid Marine Acid Acetous Acid Fixed Air	Tartar Vitriolat. Nitre Sal Digestivus Tartar Regenerat. Mild Fixed Alcali	Vitriolic Acid Nitrous Acid Marine Acid Vegetable Acid Fixed Air	Sal Glauberi Nitrum Cubicum Common Salt Rochel Salt Mild fossil Alcali	Vitriolic Acid Nitrous Acid Marine Acid Vegetable Acid Fixed Air	Sal Ammon. Vitriolic — Nitrous — Commun. — Vegetable Mild Volatile Alcali	Vitriolic Acid Nitrous Acid Marine Acid Vegetable Acid Fixed Air Water	Selenitis — Nitrous Liquid shell Quick Lime Lime Water
9. EARTH OF MAGNESIA.		10. METALS.		11. PHLOGISTON.		12. SULPHUR.	
Vitriolic Acid Nitrous Acid Marine Acid Vegetable Acid Fixed Air	Epsom Salt Magnesia	Marine Acid Vitriolic Acid Nitrous Acid Acetous Acid		Air Vitriolic Acid Phosphoric Acid Metallic Calces Veget. & Anim. Earth	Phlogisticated Air Sulphur Phosphorus Metals Coal	Fixed Alcali Absorb. Earth Volatile Alcali Iron Reg. of Antim. Mercury	Hepar Sulphuris — Nitrous Antimony Cinnabar
13. SPIRIT OF WINE.		14. WATER.		15. FIXED AIR.		16. PURE AIR.	
Water Essential Oils	Spirit. Vin. ten. Essences	Spirit of Wine Volatile Alcali	Sp. of Sal Ammoniac	Calcareous Earth Earth of Magnesia Fixed Alcali Volatile Alcali	Chalk Magnesia Mild Fixed Alcali Mild Volatile Alcali	Phlogiston Fire ?	Phlogisticat. Air

## OF CHEMICAL COMBINATION AND DECOMPOSITION.

The later writers on chemistry have comprised almost the whole of this branch of the science into a brief synopsis, which they call the Table of Affinities, or *Elective Attractions*; wherein the several substances are disposed according to the relations, or attractions which they have to each other, and on which the operations of chemistry for the most part depend. The annexed scheme contains as much of these tables as was judged necessary to the present purpose. To understand this table, you must observe, that the substance at the top of any column, combined with either of the substances beneath it, form the compound wrote against the latter on the right hand. Thus vitriolic acid, and fixed vegetable alcali, form vitriolated tartar. And you are farther to observe, that the substance at the top of a column is capable of attracting and combining with any of the substances underneath it, but that the combination is weakest with those substances which are at the greatest distance. Also when any one of the substances in a column is combined with that at the top of that column, any of the substances above it will, by means of a superior attraction, unite with the latter, and expel the former.



For

For example; it will be seen by the thirteenth column, that spirit of wine will unite with essential oil. Thus, oil of peppermint, mixed with spirit of wine, forms essence of peppermint. But water is above essential oil in the column, which shews, that there is a stronger attraction between spirit of wine and water, than between that spirit and oil. If therefore water be added to essence of peppermint, the spirit will let go the oil, to combine with the water. Hence we find, that when essence of peppermint is mixed with water, a milky appearance ensues, occasioned by the separated oil; which, after a while, rises to the surface, leaving the liquid beneath it clear.

Having thus given a general idea of the table, and doctrine of affinities, or elective attractions, I shall proceed to the subject proposed. In each process, I shall mention, as far as may be necessary, the circumstances or conditions requisite to be observed; and as vitriolated tartar is one of the most obvious instances of chemical combination, I shall begin with it.

This neutral salt is composed of vitriolic acid, and caustic fixed vegetable alcali, as you will find by the table, in the columns for those principles. But vitriolic acid is not to be met with pure. The most simple that we have, is combined with water, in the form of spirit of vitriol; the alcali however, may be had pure. Thus,  
the

the lapis septicus, or potential cautery, is the pure fixed vegetable alcali. If this alcali be added to the spirit of vitriol, it will attract the acid from the water, or in other words, the particles of the acid, being more powerfully attracted by the particles of the alcali than by those of the water, will quit the latter to combine with the former. If only just as much alcali be added as is sufficient to saturate the acid, the mixture will contain nothing but vitriolated tartar, and water; the water may be evaporated by heat, and the neutral salt will remain behind; or if it be required in crystals, the evaporation may be only carried on in part, and then the mixture set in a cool place, for the crystals to shoot, as directed in books of practical chemistry.

When these ingredients are mixed in such proportions as perfectly to saturate each other, the acid will have lost its sour taste, and the alcali its acrid one. This mutual loss of taste, is a very remarkable circumstance. Oil of vitriol is the most caustic of all acids, and has perhaps, the strongest taste of any other known substance. The taste and causticity of the alcali are almost as great. Both of them pain and burn the flesh in a manner almost similar to fire. Yet when these two principles are combined, they form a substance which has hardly any taste, or none resembling that of either of the ingredients. This loss of taste is generally proportional to the force with

with which the ingredients combine. Thus vitriolic acid and water, or oil of vitriol, has a very strong taste. If it be combined with volatile alcali, its taste is weaker, because it attracts that substance more powerfully than it does water, or exhausts on it more of its attracting force. If it be combined with fixed alcali, as above, the taste is still less; and if with phlogiston, as in sulphur, its taste is entirely lost. Its attraction to phlogiston is so strong, that it seems to exert its whole attractive power on it, and therefore with its loss of attraction, loses its taste; for taste being caused by the attraction between the tongue and the substance applied to it, if the substance has no attractive force remaining, it can have no taste.

So again, the caustic fixed alcali has a very powerful taste. When it is combined with fixed air, as in the mild vegetable alcali, the taste is less. When with the muriatic acid, as in common salt, it is still weaker, and when with vitriolic acid, as above, least of all; its taste being less, as the force of its attraction is more exhausted. This rule may be applied to other acids, alcalis, and earths. There are, however, some exceptions to it, which yet perhaps may depend on other causes. Thus, nitre has a stronger taste than soluble tartar, and tart. vitriolat. than selenitis, though the attractions of their respective ingredients are the reverse; as may be seen by the table.

Vitriolated

Vitriolated tartar may be made, not only in the manner described above, but with many substances which contain the two ingredients of which it is composed; and the salt may afterwards be extracted from the mixture by chemical art. For example,

Mild fixed alcali is a combination of the pure fixed alcali with fixed air. If this be used instead of the pure, the alcali will quit the fixable air with which it is combined, and unite with the acid, by which it is more powerfully attracted. The air thus let go by the alcali, resumes its elastic state, and by its flight causeth an effervescence in the liquid. What remains is the same mixture of vitriolated tartar and water as in the former process, and the salt may be obtained from it in the same manner.

Green vitriol is a combination of vitriolic acid with iron. If caustic fixed alcali be added to this compound, the acid quits the iron to unite with the alcali, by which it is more powerfully attracted; the iron will settle at the bottom in form of a powder, from which the clear liquor may be poured off, and the salt may be separated from the water in the manner already described. The like may be observed of the other vitriols, of alum, and of Epsom salt.

But

But it is worthy of remark, that if this last substance, and mild fixed alcali be used, the fixable air of the latter will not fly off in its elastic state in the manner described above, but unite with the magnesia separated from the Epsom salt by the alcali, so that there will be two new compounds formed. The Epsom salt is vitriolic acid combined with magnesia; the acid, uniting with the alcali, forms vitriolated tartar; and the magnesia, uniting with the fixable air, forms the common mild or uncalcined magnesia, for it must be observed, that the *calcined*, is the pure magnesia, the *common* is magnesia combined with fixable air, like the mild alcali. The same double decomposition takes place when selenitis and mild alcali are used, and in many other cases, and this is called *double affinity*, or *double elective attraction*, as the former is termed *single*, because there are two new compounds produced in the latter case, and only one in the former.

Again, nitre is a combination of fixed vegetable alcali with nitrous acid, as you will find by the table. But if oil of vitriol be added, the alcali will quit the nitrous acid to unite with the vitriolic, by which it is more powerfully attracted, and the nitrous acid will unite with the water; so that here also we have a double affinity. The mixture therefore is now vitriolated tartar, and spirit of nitre. The latter may be distilled over with

with a sufficient degree of heat, leaving the former behind.

Vitriolated tartar may be obtained in like manner from sal digestivus, and from regenerated tartar, by adding to them the vitriolic acid, with this only difference, that spirit of salt and vegetable acid are respectively obtained instead of spirit of nitre.

What has been said of vitriolated tartar may be applied in great measure to nitre and sea salt.

Thus, by mixing spirit of nitre with pure vegetable alcali, nitre may be obtained in like manner as tart. vitriol. was from the same alcali and spirit of vitriol. If nitrous acid be combined with some other substance, to which it has a weaker attraction than to the vegetable alcali, nitre may be formed, as tart. vitriolat. was with green vitriol, and alcali. Also, if the fixed vegetable alcali be combined with any substance, by which it is less strongly attracted than by the nitrous acid, nitre may be made by adding the nitrous acid, as vitriolated tartar was made by adding spirit of vitriol to nitre, sal digestivus, or regenerated tartar.

So sea salt may be formed by adding spirit of salt to natron; or with spirit of salt and sal Rochel: or with natron and sal ammoniac, but  
ter

ter of antimony, or corrosive sublimate of mercury.

So likewise regenerated tartar may be formed with fixed alcali and vegetable acid ; with fixed alcali and sugar of lead ; with fixed alcali and spiritus Mindereri ; and the like. All which require no explanation, as they will be easily understood from what has been said of vitriolated tartar. Yet, to render the doctrine of chemical composition still more clear, I shall give another instance in *sal ammoniac*.

If spirit of salt (which is a combination of marine acid with water) be mixed with sp. sal ammoniac, cum calce (which is the caustic volatile alcali, also combined with water) to the point of saturation, the mixture will be common sal ammoniac, and water : The water may be separated from the salt by evaporation, or crystallization, as shewn before ; or the salt may be sublimed into a cake, like the sal ammoniac of the shops. For the ingredients being both volatile, and strongly attracting each other, they will rise in vapour in their combined form, as hath already been shewn \*.

In this case the volatile alcali entirely loseth its very powerful smell, its particles being attracted

\* A mixture of alkaline, with marine acid air, forms this salt, as was shewn in a former chapter.

tracted, and as it were, fixed by those of the acid. The taste also is nothing comparable to that of the acid, or even of the alcali in strength, for reasons already given.

If the mild volatile alcali be used, the fixed air will be expelled, and fly off (hence the violent effervescence;) and therefore the mixture will be sal ammoniac and water, as when the caustic alcali was used.

If the acid be combined with another substance to which it has a weaker attraction than to the volatile alcali, it will quit its union with that substance to unite with the alcali. Thus, if merc. corr. subl. be mixed with the volatile alcali, the acid will leave the mercury, and form sal ammoniac with the salt. The mercury thus disengaged, will fall to the bottom in the form of a powder, and the sal ammoniac may be obtained from the clear water in the manner already described.

Also if the volatile alcali be combined with a substance to which it has a less affinity than to the marine acid, the alcali will quit that substance, and form sal ammoniac with the acid. Thus, spiritus Mindereri is this alcali combined with the vegetable acid. But spirit of salt being added, the alcali will leave the vegetable, to form sal ammoniac with the marine acid. The salt may

I be

be separated from the liquor by crystallization; or by other means.

These instances will be sufficient to give you an idea of chemical combination. I shall now give a few examples of decomposition.

We may decompose a compound chemically, by knowing its ingredients, and duly applying a principle to which one of the ingredients has a stronger attraction than to that with which it is already combined. The table of affinities affords a variety of such instances.

Let it be required, for example, to decompose sal ammoniac, so as to obtain its volatile alcali. By examining the table, I find that sal ammoniac is a combination of the volatile alcali with marine acid. In the column for that acid I find, that natron, among other substances, is above the volatile alcali. Marine acid therefore has a stronger attraction to the fossil than to the volatile alcali, and therefore will leave the latter to unite with the former. The mixture will be the volatile alcali, and common salt. As a proof of this, as soon as the ingredients touch each other, though before, they were destitute of odour, yet now a very strong smell of volatile alcali is perceived: and as the alcali is volatile, the salt fixed, we have only to put the mixture into a retort, and a due degree of heat will force over the alcali, leaving the sea-salt behind.

It.

It may be observed, that if the caustic fossil alcali be used, the volatile alcali obtained will also be caustic. But this is always in a fluid state, as before observed. To obtain a solid, and therefore mild salt, the natron must be used in its mild state. The fixed air of which is transferred to the volatile alcali, as the natron is to the acid; so that here again is a double affinity, a double decomposition, and two new combinations \*.

The volatile alcali may likewise be obtained from sal ammoniac, by using calcareous earth, or fixed vegetable alcali, instead of natron; and it may also be had either caustic or mild, according to the state in which these substances are used.

To decompose sal ammoniac so as to obtain its acid. In the column for volatile alcali, above marine acid you find, among others, the vitriolic. If you mix oil of vitriol with sal ammoniac, the volatile alcali will quit the marine acid, and form, with the vitriolic, sal ammon. vitriolic. The mixture therefore will be this salt, and the marine acid combined with the water of the oil of vitriol, which may be obtained from the salt by distillation, as being more volatile.

This may also be done by using the nitrous acid. But practitioners prefer the vitriolic, be-

\* The mild alcali may also be composed directly, by mixing fixed, with alkaline air. See the chapter on different kinds of air.

cause part of the nitrous is apt to pass over with the marine in distillation; so that instead of the pure spirit of salt, you have aqua regia, or a compound of the spirits of nitre and of salt.

Substances containing the vitriolic acid may likewise be used, and the nitrous and vegetable sal ammoniacs may be decomposed by methods similar to those above described.

These instances will be sufficient to give an idea of chemical combination and decomposition, and enable you to understand not only the other instances in the table, but also the reason of many processes which you meet with in dispensaries, and books of practical chemistry. But these points will be further elucidated by what follows to the end of this chapter.

In the fourth chapter, I gave a synopsis of the neutral salts, and shewed that each of them was a compound of a particular acid with some alcali. From what has been said of vitriolated tartar, and sal ammoniac, you will understand in general the manner in which these salts are obtainable from their respective principles. The like may be observed of the metallic and earthy salts in the same chapter.

These salts may likewise be decomposed on the same principle as hath been shewn of sal ammoniac.

It must however, be observed, that the circumstances attending the processes require to be varied in some particular cases, though the principles on which those processes depend are the same; and hence the particular directions for conducting those different processes, to be met with in books of practical chemistry. I shall give a few instances by way of illustration.

Green vitriol is a combination of the vitriolic acid with iron. But if you add iron to oil of vitriol, this salt cannot be made. For in order to the solution of the iron, the oil of vitriol must be previously diluted with water.

Corrosive sublimate is a compound of marine acid with mercury. Mercury, however, cannot be dissolved by that acid in a liquid form. In order to their combination, they must be raised into fume, and in this state the ingredients unite, though they could not in their coherent form. Hence in this process, vitriol and common salt are employed. The acid of the vitriol disengages that of the salt, which rising in vapours, meets with the mercury, also raised in vapours, for which purpose it had been previously dissolved in the nitrous acid, in order that it might be reduced into its smallest particles.

So in decomposition, if green vitriol be mixed with nitre, the acid of the vitriol must be expelled by the force of heat before it can act on the nitre

so as to disengage its acid. Without this circumstance no nitrous acid is obtained.

But further to illustrate this subject, I will run through the whole of one of the columns for salts, together with certain other processes, proper for our purpose, noting the circumstances requisite to be observed towards forming the several decompositions and combinations.

Spirit of vitriol is a combination of vitriolic acid with water. If to this compound you add thin plates of copper, and give a due degree of heat, the copper will be dissolved. The mixture therefore will now be blue vitriol and water, which might easily be separated by the methods already described. If to this solution you add plates of iron, the acid will leave the copper and unite with the iron. As the latter dissolves, and the former is let go by the acid, it deposits itself upon the surfaces of the iron plates, so that they look like copper. But when the iron is all dissolved, the copper will fall to the bottom in form of a powder. The clear liquor being decanted, will therefore be a mixture of water and green vitriol; if to this solution zinc be added, the acid will leave the iron by degrees, and unite with the zinc, and the iron will fall to the bottom in form of a powder, as the copper did before. The clear liquor being decanted, will be a solution of white vitriol in water. Add volatile  
alcali

alcali to this solution, the acid will leave the zinc to unite with the salt; the zinc will fall to the bottom in form of a powder, and the clear liquid being decanted, will be vitriolic sal ammoniac and water. Add fixed alcali to this liquid, the acid will unite with it, letting go the volatile, and the mixture will be vitriolated tartar, and spirit of sal ammoniac. The latter may be obtained by distillation, the former remaining behind. Mix this salt with an equal quantity of fixed alcali, and add powdered charcoal equal to about a fourth part of the weight of the whole. The charcoal, you will observe, contains phlogiston combined with a vegetable earth, and the alcali is added to make the vitriolated tartar melt, which it will not easily do without such addition. Put these ingredients into a crucible, covered, and apply a sudden and strong heat for a short time, the vitriolic acid will leave the fixed alcali to unite with the phlogiston of the charcoal. The mixture therefore is now common sulphur, fixed alcali, and vegetable earth, that is, it is an impure *liver of sulphur*. Dissolve the mass in water, the earth will subside, and the clear liquid will be a solution of liver of sulphur and alcali, in water. Decant, or filter this liquid; and to obtain the sulphur, look in the table for fixed alcali, you will find above sulphur several acids, add a sufficient quantity of either of these, the alcali will quit the sulphur to unite with the acid,

acid, and the sulphur will fall in a powder to the bottom, which you may separate from the liquid, and melt into a roll. And thus will you have had successively spirit of vitriol, blue vitriol, green vitriol, white vitriol, vitriolic sal ammoniac, vitriolated tartar, and sulphur, each of which might have been easily obtained in their usual forms.

In the column for sulphur, you find that sulphur and mercury form cinnabar. There is, however, no method of combining these ingredients into that form, either by dry-mixture or liquefaction. If they are mixed in either of these ways they form not cinnabar, but Æthiops mineral. To combine them into the form required, they must be raised in vapour. If they be first mixed into an Æthiops, and then sublimed, cinnabar will be the sublimed substance.

To decompose this compound so as to obtain the mercury, look in the column for sulphur, and you will find, above mercury, fixed alkali. But as that forms an hepar sulphuris with the other ingredient, there is a difficulty in obtaining the mercury to advantage. The other ingredients have also their inconveniences, and, therefore, iron is used. By mixing iron-filings with the cinnabar, and distilling them in a retort, the sulphur is attracted by the iron from the mercury, which rises pure into the receiver, (filled with water

water to condense the fumes,) the sulphur and iron remaining behind.

Sulphur and fixed alcali form liver of sulphur. This, however, they do not do by mere mixture; they are to be placed on the fire so as just to melt the sulphur, and the mixture is to be continually stirred, till the combination is formed. If the mild alcali is used, it will not unite with the sulphur till its fixed air is expelled. You may obtain the sulphur from the alcali again by sublimation; but the better way is to add some acid to attract the alcali from it, the sulphur will then be precipitated in form of a white powder. By washing and melting, it may be restored to its pristine form.

In the column for water you will find mild volatile alcali, which forms spirit of sal ammoniac. Imagine this as strong as it can be made. Above volatile alcali you will find spirit of wine, which you must likewise suppose to be as strong as possible. If these are mixed, the spirit of wine will attract the water from the salt, which will therefore be instantly restored to its solid state, forming that beautiful experiment of Van Helmont of the *offa alba*.

In the column of fixable air, (for the philosophy of which, in this view, we are indebted to the learned and ingenious Dr. Black,) you will find

find that the volatile alcali and this principle form the mild volatile alcali. Fixed alcali is above the volatile in the column. If to the pure fixed alcali, dissolved in water, you add the mild volatile alcali, the fixed air will be attracted by the former from the latter, which, with the water, may be distilled over in the form of caustic volatile alcali; the fixed alcali, now rendered mild, remaining behind.

If to this alcali, dissolved in water, you add the caustic magnesia, the latter will attract the fixed air from the former, and the mild magnesia and caustic fixed alcali may be obtained separate by filtration, &c.

If to the magnesia, mixed with a due quantity of water, quicklime be added, the fixed air will leave the magnesia to unite with the lime, forming common calcareous earth. It is observable that calcareous earth is soluble in water when in its caustic state, forming what we call lime-water; but mild calcareous earth is not soluble in that liquid. It is also observable that any of these substances will become mild by being exposed to the fixable air escaping from an effervescent mixture, which it will attract or absorb. And they will do the same in time if exposed to common air, because there are always many particles of fixable air floating in the atmosphere, which these substances imbibe. Hence if

if lime-water be exposed to the air, a white crust forms upon its surface, which is nothing but the lime now become no longer soluble by reason of its combination with fixed air. And if fixable air be mixed with lime-water, the lime, which before remained dissolved, will be precipitated in form of a white powder, for the same reason. Hence it is that lime-water is a test of the presence of fixed air, as mentioned in a former chapter. These processes contain such a variety of combinations and decompositions, with the circumstances relating to them, that to a person of common capacity, nothing farther needs be said on the subject.

I shall conclude this account with the rationale of some processes depending on *phlogiston*, the most extraordinary perhaps, of all the chemical principles.

Metals are combinations of their respective earths or calces, with this subtil principle.

If an acid be applied to a metal which it can dissolve, the calx, having a greater affinity to the acid than to the phlogiston, quits the latter to unite with the former. The phlogiston attaches itself to the vapour and air which arise on these occasions, and with them fly off.

Metallic

Metallic salts, and solutions therefore are not combinations of acids with metals, but only with their calces.

If a metal dissolved in an acid be precipitated by any metallic calx, or by any other substances besides a real metal, the precipitate will not be a metal, but a calx. Thus if copper be dissolved in vitriolic acid, the solution only contains the calx of the copper, the phlogiston having escaped. If calx of iron, fixed alcali, or the like be added, the acid will unite with these, letting go the calx of copper, which therefore will fall to the bottom only in the form of a calx.

But if to this solution of copper, iron or zinc be added in their metallic state, or as they are combined with phlogiston, a double affinity takes place. The calx of the added metal unites with the acid, and its phlogiston with the precipitated calx; so that the powder at the bottom is now not calx of copper, but copper itself. And this is the case in all metallic solutions, when the precipitation is made with a metal.

Charcoal is a combination of vegetable earth with phlogiston, as you will find by the table. If calamine stone be properly fused with the charcoal, the calx will attract away its phlogiston and be formed by it into a metal. This metal is zinc. If the phosphoric acid be added to this metal,

metal, and they be distilled in a retort, with a sufficient heat, the phlogiston will quit the metal to unite with the acid, and the phosphorus formed by their union, will distil over into the receiver (which must be filled with water to condense and quench the vapours) the calx remaining behind. This compound is the famous substance known by its property of shining in the dark, and burning in the ordinary heat of the atmosphere. It is usually obtained, by a very laborious process from urine. In the urine is a particular kind of salt, called by chemists the fusible salt of urine. It consists of the phosphoric acid united to an alcali, like other neutral salts. In the course of the process, the acid quits the alcali and unites with the phlogiston of the urine into phosphorus, in the same manner as in the process of making sulphur with charcoal and vitriolated tartar, or Glauber's salt. But if this salt be extracted from the urine by crystallization, and then mixed with charcoal, or other proper phlogisticated substance, and distilled with a sufficient heat, the same phosphorus will be formed. Phosphorus therefore is only a particular kind of sulphur burning with less heat than common sulphur. If *pure* vitriolic acid and this substance were mixed together, and distilled, the phlogiston would quit the phosphoric to unite with the vitriolic acid. The sulphur formed by their union would be sublimed by a proper degree of heat, leaving the phosphoric acid behind. If this sulphur

phur be mixed with, or exposed to the action of air, and a proper degree of heat be applied, the phlogiston will quit the vitriolic acid to unite with the air, by which it is more powerfully attracted, and the acid remain alone in vapours, which may be caught and condensed, by means of the steam of water, into common spirit of vitriol, or spiritus sulphuris per campanam.

Other bodies containing phlogiston not too strongly combined may be decomposed by air as well as sulphur. The air decomposes phosphorus in the usual heat of the atmosphere; but most other bodies require heat for that purpose. Thus oils and fats require a greater heat than sulphur; and metals are not decomposed by air without an intense degree. The heat enables the air to act on the body and attract from it its phlogiston, which it could not do before. Thus also it has been seen that many decompositions of other kinds can be effected without heat, but that there are others of them to which heat is necessary.

The decomposition of phlogisticated bodies by air, I had occasion to treat of in the chapter on different kinds of air; and in the chapter on fire was given the present theory of the heat attending some of these processes. To account for the heat in combustion let it be supposed that a great quantity of fire is contained in air, in a fixed, or latent state. In combustion the phlogiston of the

the inflammable body is transferred to the air, the fire is set at liberty by reason that it has a weaker attraction, and produces the great degree of heat observable on these occasions ? (See the table, column 16.)

The more rapidly the decomposition proceeds, that is, the greater the quantity of it which takes place in a given time, the greater will be the heat. Hence bellows, blow-pipes, and currents of air, by applying fresh particles of air to the body, are successfully employed for that purpose. Also the heat will be greater according as the air is more pure. Hence with dephlogisticated air, the heat is much greater than when common air is employed.

Bodies containing phlogiston in the manner above described, are called *combustible bodies*, and their decomposition by air is called *combustion* or burning, on account of the heat attending it. But the combustion of bodies may be effected by means of nitrous acid as well as by air. Nitre contains a quantity of pure air in a state of combination, as fixed air is contained in marble, &c. when nitre therefore is mixed with a combustible body, and a due degree of heat is applied, the phlogiston and air mutually attract each other from the substances with which they were before combined, and unite ; and heat is generated on the principle already explained. See also the chapters on fire, and the different kinds of air.

C O N-

## C O N C L U S I O N .

WHAT has been said will, it is presumed, be sufficient to give the reader a general idea of chemical elective attraction, and enable him to reason on the operations which depend on it. With a few remarks on what has been said, I shall close this part of my subject. These remarks however, will be such as would, at least for the most part, naturally occur to a reader of tolerable capacity after having gone through the preceding chapters.

## I.

Bodies cannot act on one another, unless one of them at least be in a fluid, or vapoury state. In these states the particles of one body are free to exert their action on those of another, which, in a solid state they cannot do, by reason of the great attraction which takes place among themselves.

## 2.

In many cases heat is necessary to the action of bodies on each other. Thus mild fixed alcali and sulphur will not form hepar sulphuris without heat: and calces with inflammable substances will

will not become metals but by means of the same agent. In those cases wherein bodies act on each other in the usual temperature of the atmosphere heat usually very much promotes the effect. Thus, cold water will dissolve sugar; but if heat be applied, the solution takes place more speedily, and also in greater proportion. Heat is also the agent in the preceding remark. If ice cannot dissolve sugar, it is only for want of sufficient heat to render the former ingredient fluid. If spirit of salt cannot form corrosive sublimate with mercury, it is only because there is not a sufficient heat to reduce them into vapour.

## 3.

In explaining the table of affinities, I have sometimes mentioned a compound only in the light of a principle, or ingredient. Thus, at the head of one of the columns is sulphur, which yet in another column is given as a compound of the vitriolic acid, and phlogiston. But with respect to the substances underneath it in the column, it is a principle; those substances not decomposing, but uniting with it, as it is sulphur. Thus, mercury and sulphur are the proper constituent principles of cinnabar; and so of others:

Also many of those which appear to be principles are in fact only compounds. Thus, alcaline salts are combinations of earth, acid, and phlo-

K

giston.

giston. So likewise acids, &c. are only compounds of other and more simple principles.

## 4.

In many cases the union of bodies, according to the course of their affinities, will not take place but under particular circumstances. Thus, phlogiston will not decompose vitriolated tartar, but in a violent degree of heat. Mercury and the marine acid will not combine but in the form of vapour; and so of others. It may also be observed, that a combination cannot be effected in some cases, but by previously uniting the substance with another, to which it has a weaker attraction. For example, æther will not dissolve gold; yet if gold be dissolved in aqua regia, and then the æther be added, the latter will attract the gold from the former; and chemistry furnishes other instances of a like kind.

## 5.

In some cases two principles which will not unite, may yet be made to do so, by means of a third principle, which has an attraction for both. Thus sulphur will not unite with water, but if the sulphur be previously combined with an alcali, the water, by reason that it strongly attracts the salt, retains also the sulphur, which the alcali, on its union with the water, does not let go. So likewise oil and water will not mix; but if an alcali, which attracts both, be added, their mixture will, by means of this intermedium, be effected.

6. From

## 6.

From what has been said concerning the table of affinities, the reader will be enabled, with a little attention, to understand many particulars of the philosophy of chemistry, not there discoursed of. For example, he will now be capable of comprehending the reasonings of chemical writers, when treating of the theory of their art, or giving the rationale of any particular process; which was what was chiefly intended by these elements: and I should hope that he will also be able to discover the theory of many of those processes, even without such aid. For exercise in these particulars I would refer him to the operations concerning metals; to the several processes for making the æthers; and to others, which I have not touched upon; examples of which he will find in abundance in chemical and pharmaceutical writings.

## 7.

He will also be enabled to comprehend the reason of the several general operations of chemistry. For instance,

## P R E C I P I T A T I O N ,

Or the displacing or expelling of one principle from another by means of a third, on account of a superior affinity. Thus, if sulphur be dissolved in an alkaline liquor, and an acid be added, the alkali unites with the acid, letting go the sul-

phur, which therefore falls to the bottom, in form of a powder, called from hence, *sulphur precipitatum*. Thus likewise, if an essential oil be dissolved in spirit of wine, and water be added, the spirit of wine unites with the water, and lets go the oil, which rises in the liquid, and floats on the surface; this is likewise called precipitation; and fixed air, when disengaged by an acid, and flies off from the liquid, is also said to be *precipitated*.

#### CRYSTALLIZATION,

Which happens when particles of salt are suspended in too small a quantity of liquid, or in a liquid not sufficiently hot; for the particles running together, form themselves into those regular, transparent clusters, or masses, which we call crystals. As some salts require a greater quantity of water than others to keep them dissolved, if more than one sort is dissolved in any liquid, that which requires the greatest quantity of water to keep it dissolved, will crystallize before the other; and hence the art of obtaining the several salts dissolved in any liquid separate; hence also several kinds of salts when mixed together, may be separated on this principle. Common salt, for example, dissolves in less water than nitre: hence if nitre and common salt be dissolved in the same liquid, the nitre will crystallize soonest, and therefore may, by a proper management of the evaporation, be obtained before

before the common salt begins to shoot. As nitre when first made contains a large quantity of common salt, it is purified from it by this method.

#### DISTILLATION,

Or the raising of any volatile substance by heat into vapour, and making it pass over into a proper receiver, where it is condensed. Similar to which is

#### SUBLIMATION,

Or the raising of certain volatile matters in dry fumes which form themselves into a powder, or hard solid mass in the upper part of the vessel, or in a receiver.

#### CALCINATION,

Which is of two kinds. 1. Where the volatile matters are driven from the fixed, by means of fire in open vessels, or in the open fire, as is the case with magnesia, quicklime, and some other substances; and 2. When the phlogiston is to be taken from a substance by a like exposure to heat; this is more properly called combustion. Thus, lead, antimony, &c. are reduced to calces, that is, are deprived of their phlogiston by calcination in open vessels; the air attracting their phlogiston in like manner as was shewn of the combustion of sulphur, and other bodies; but the decomposition in these cases, proceeding but very slowly, a degree of heat is not generated sufficient for the continuance of the combustion

as happens in those bodies, and therefore the application of extraneous heat is also necessary. There are other calcinations which partake of both these kinds.

## CONCENTRATION,

Or the reducing of any principle not obtainable in a separate state, into as small a compass, or in other words, making it as strong, as possible. Thus, oil of vitriol is concentrated by evaporating its superfluous water; the stronger and less volatile acid remaining behind. Spirit of wine is concentrated by distilling it with a very gentle heat, so that as little water may rise with it as may be: which concentration is effected in a direct contrary manner to the other, the spirit being more volatile than the water; the water more volatile than the acid. There are also other methods of concentration: thus, vinegar may be concentrated by freezing; the watry part only congealing, which may therefore be taken out in the form of ice, the remaining acid being so much the stronger. Hot, dry salt of tartar added to rectified spirit of wine, attracts water from it, after no more can be obtained by distillation. Vinegar again may be saturated with an alcali, and thereby formed into a neutral salt. To this salt made dry, concentrated oil of vitriol being added, the vinegar is expelled by means of a superior affinity, as was shewn in the distillation of spirit of nitre and spirit of salt, by which means

the

the vinegar receives the highest possible degree of concentration ; and other instances of concentration may be met with in chemical writers.

## 8.

An acquaintance with chemical theory will also enable him to analyze compounds, so as to discover their ingredients. If, for example, I would know the composition of a neutral salt, presented to me for that purpose ; I dissolve part of the salt in water, and add a fixed alcali. As there is no turbidness, I conclude, that the basis of the salt is neither earthy nor metallic. I apply my nostrils to the liquid, and find that it smells strongly of the volatile alcali, which therefore I conclude to be the alkaline basis of the salt.

I pour on the salt a little oil of vitriol, and immediately perceive fumes to arise. I therefore conclude that the acid of the salt is not the vitriolic. On examining the colour of the fumes, I find it to be red. The salt therefore is probably a combination of nitrous acid with volatile alcali ; that is, the nitrous sal ammoniac.

To be further satisfied of this I grind a little of it with spirit of wine, and find that it totally dissolves therein. I place another quantity of it in a shovel over the fire, without any mixture of inflammable substance, and it explodes. From all these circumstances I safely conclude that the

salt is the nitrous ammoniac, as I before conjectured. For no other answers to that description; and in particular it is the property of this salt alone to detonate without addition.

If there be presented to me a solution of two different salts in water, and I am required to discover them, I add to a little of the liquid, some fixed alcali, and find a turbidness, together with a smell of volatile alcali. One of the salts therefore is ammoniacal, the other either earthy or metallic. I collect, and wash the precipitated powder, and find that it is perfectly white, that it readily dissolves in the vitriolic acid, with effervescence, and is precipitated from it by volatile alcali. It is therefore probably magnesia. I evaporate and crystallize this latter solution, the salt shoots into long slender crystals, and appears like the sal catharticus ainarus, another argument that the basis is magnesia.

To discover the acids, I evaporate a sufficient quantity of the original liquid, and on part of the crystals first obtained, pour a little oil of vitriol; a white fume arises, which shews that the acid of those crystals is the marine. To another part of them I add fixed alcali, and find a smell of volatile alcali; from whence I conclude that one of the salts is the common sal ammoniac.

As the basis of the other was magnesia, I add to the liquor from which I obtained the crystals of

of sal ammoniac, a sufficient quantity of fixed alcali to precipitate the whole of the powder. I evaporate the clear liquid, and pour on part of the first crystals obtained some vitriolic acid. But no fume whatever arises. The salt therefore is probably vitriolated tartar. I expose it to the fire, and it crackles like that salt; it does not fuse; it is difficultly soluble in water. These characteristics, together with its taste, and the form of its crystals, leave no doubt of its being vitriolated tartar, as I before imagined. The two salts in the original solution therefore were sal ammoniac, and sal catharticus amarus.

By knowing the properties of saline substances, and the doctrine of chemical affinities, sophistifications may be detected. If for example the sal catharticus amarus be imposed on me for the true Glauber's salt, which it may be made to resemble in the form of its crystals; by adding a little fixed alcali to a solution of the salt in water, the cloudiness occasioned by the precipitation of the magnesia, discovers the fraud.

If I would examine the purity of a powder sold me for magnesia, I pour on it vitriolic acid; if the solution is perfectly transparent, I may pretty safely conclude, that the powder is genuine, especially if by evaporating and crystallizing the liquid, a true sal catharticus amarus is obtained.

tained. But if the solution deposited a sediment, or any other than Epsom salt is obtained from it, the magnesia may be concluded to be impure.

The reader who has a genius for chemistry, will be readily enabled to extend these hints to other chemical substances; and I would recommend this kind of analysis to him, as the most likely means of improving him in this branch of science.

## P O S T S C R I P T.

SINCE the preceding sections were written, the tables of the celebrated Professor Bergman have fallen into my hands. As these admirable tables are not yet published in any English work, and are not generally known, I have subjoined them to the *chemical* part of this treatise, by way of exercise to the student. They will also be useful to proficients in chemistry; as they contain, in a manner, all that has yet been discovered in that art.

The first of these tables is that of *simple elective attractions*. It is divided into two parts. The upper respects the *humid*, the lower the *dry* way of chemical combination.

This division is very proper. For attraction will sometimes take place in one of these cases, though it will not at all, or in a different manner, in the other. The vitriolic acid, for example, will not unite with phlogiston, so as to form sulphur in the *humid* way, or with water: yet in the *dry* way, phlogiston takes place of ponderous earth; which, in the *humid* way, stands immediately under that acid.

In former tables the vegetable acids were considered as the same. In this they have their separate columns; and their attractions appear to be scarce less different from one another, than from the other acids. Former tables also reckoned but three mineral acids. In this, more than double that number will be found, with equal variety of attractions.

The mineral and vegetable fixed alcalis were thought to have the same attractive force to acids: By this table it will be seen that the attraction of the vegetable alcali is stronger than that of the mineral.

Substances, with their elective attractions, are also to be met with in this table, which are not to be found in those of Geoffroy or Gellert; as the ponderous earth; manganese, acid of spar, and others.

The reader who has attended to the directions for the former table, will find no difficulty in understanding this, after having learnt the characters.

The second of these tables relates to double elective attractions, and chemical operations.

By the character of *water* in the middle of some of them, the *humid way* is meant. By the character of *air*, the *dry way*.

Figure

In these figures the effects of mixing different bodies are shewn. Always one, and often both of the bodies whose mixture these diagrams represent are compounded; and the chemical character expressing the compound is placed on one side of an *upright circumflex or bracket*, (thus {) with the characters expressing its ingredients on the other. In the 21st figure, for example, the effects of mixing vitriolated tartar with fixed ammoniac is represented, both which are compounds. On the left is placed the character of the tart. vitriol, also separated by an *upright bracket* from the characters of its two ingredients. On the right stands the mark of the fixed ammoniac, separated in like manner from the ingredients of which it is composed.

Where the original compounds are decomposed, and new ones produced, the new composition is signified by a bracket or circumflex drawn *horizontally*; the character of the compound being placed on the outside, and the ingredients of which it is composed within. Thus, fig. 3. represents the mixture of fixed alcali with sea-salt. The sea-salt, which is a compound, is decomposed, and a new compound is formed: the marine acid quitting the mineral, and uniting with the vegetable alcali, forming sal digestivus. Where the mixture is neither accompanied with the production of a new com-

pound, nor with the decomposition of the old one, the horizontal circumflex is omitted. An instance of this occurs in fig. 2. where lime is added to tart. vitriol. without any effect being produced.

The darts which are to be seen in these schemes point out the relative force of the attractions of the respective ingredients. In fig. 21. the dart directed to vitriolic acid from calx, shews that it is as capable of decomposing the fixed ammoniac; and the dart directed to vegetable alcali from acid of salt, shews that it is capable of effecting the same decomposition by uniting with the marine acid. The dart directed to vitriolic acid from vegetable alcali, shews that that acid is capable of decomposing the sal digestivus by combining with its alcali. The calx not being able to decompose the sal digestivus, nor the marine acid the selenitis, no darts are directed towards them.

In many cases the mixture of bodies is accompanied with precipitation. When the new compound is a precipitate, its precipitation is denoted by turning the apex of the circumflex downward; as is the case with selenitis in the 21st fig. When the precipitate is not a new compound, but an ingredient of one of the old ones, it is represented by a half circumflex, the extremity

extremity of which, pointing to the right hand, is turned downwards, as is the case with lime in the fourth figure. Whenever the apex either of the whole or half horizontal bracket is not thus turned downwards, it shews that the compound or ingredient remains dissolved in the liquid.

The schemes from 1 to 20, and from 40 to 55, represent simple elective attractions. In the others the attractions are double. Double elective attraction is elegantly explained by fig. 65.

On the left hand are the ingredients forming vitriolated tartar. On the right, the salt formed by the union of nitrous acid, and calx of silver. Neither the nitrous acid, nor calx of silver, can decompose vitriolated tartar, yet both of them acting together, can do it easily. Thus, if vegetable alcali and vitriolic acid attract each other with the force 9, and the nitrous acid, and calx of silver only with the force 2, then if the nitrous acid attracts the vegetable alcali with the force 8, and the calx of silver, the vitriolic acid with the force 4; 8 and 4 is greater than 9 and 2; a decomposition therefore will be effected, and two new compounds formed; the one, of the vegetable alcali with the nitrous acid, and the other, of vitriolic acid with the calx of silver.

These

perfectly strait. Now, if a piece of paper be held any where in the strait line occupied by the thread, the sun's light will fall upon it; but if the paper be removed out of that line, this will not happen. Also, if the eye be placed any where in that line, the sun will be seen; but if it be removed from that line, the sun is no longer visible. Light therefore moves on in a right line, when no obstacle hinders, and this must be remembered as a fundamental principle in optics.

Take a flat looking-glass (Opticians call it a *plane mirror*) drill a small hole through its middle, and pass through it three threads. Suspend the mirror from the ceiling, or otherwise, by one of them, and let it down flat upon a table, in such a manner as that the light from the window-shutter may fall upon the middle of the glass, the hole being in the center of the luminous spot. Fasten the glass to the table in this situation, the light will be reflected from the glass to the opposite wall. Let one of the remaining threads be fixed to the hole in the shutter, the other at the spot on the wall, both of them, as well as the perpendicular one, being drawn perfectly strait. All things being thus ordered, you may observe that the perpendicular thread is exactly in the middle between the two others; or in other words, the angle which the thread from the window makes with



Fig. 1.

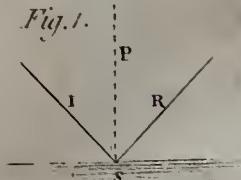


Fig. 2.

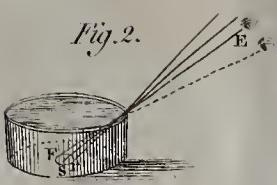


Fig. 3.

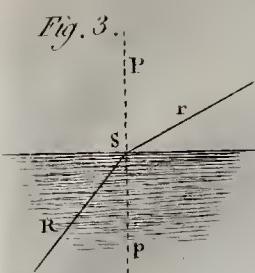
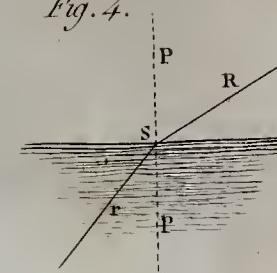


Fig. 4.



A

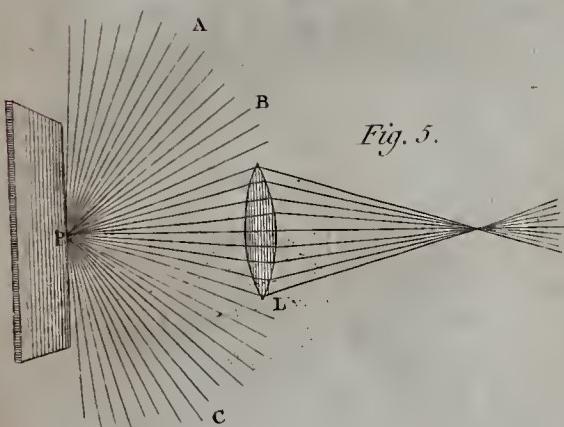


Fig. 5.

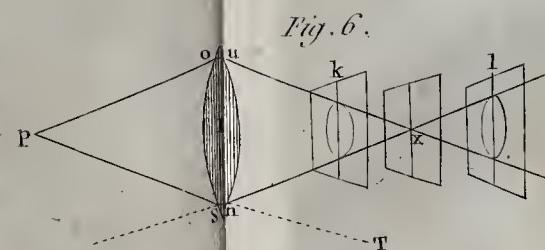


Fig. 6.

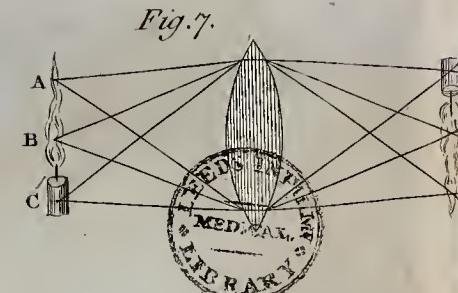


Fig. 7.

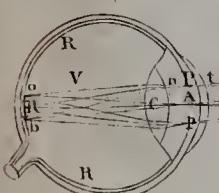


Fig. 8.

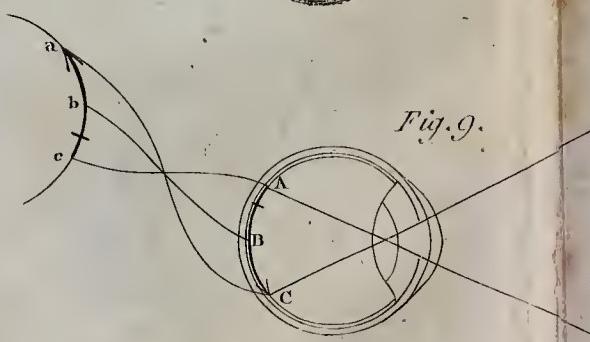


Fig. 9.

the perpendicular one, is exactly equal to that which is made with it by the thread which goes to the spot on the wall. For if you place a graduated ruler against the three strings, parallel with the table, you will find that the perpendicular one falls exactly in the middle between the others. See figure 1st.

Now the light comes in a right line from the window to the glass, and goes in another right line from the glass to the wall. The strings therefore being strait, represent these beams of light. The light which comes from the window to the glass is called *the incident light*; and that which goes from the glass to the wall, is called *the reflected light*. The angle which the incident ray (I S) (see the figure) makes with a line (P S) perpendicular to the point of the surface whereon they fall, (as the perpendicular thread in this case) is called *the angle of incidence*. That which the reflected ray (S R) makes with the same perpendicular, is called *the angle of reflection*. And it is an invariable rule in optics, *that the angle of reflection is equal to the angle of incidence*. If the angle of incidence be great, the angle of reflection will be great; if small, the angle of reflection will also be small: and if the angle of incidence be nothing, the angle of reflection will be nothing, so that the ray will be reflected back in the same line that it came.

L

When-

Whenever therefore a ray of light falls on a body, we are to imagine a line perpendicular to the point of the surface whereon the ray falls; and by knowing the angle which the ray makes with that perpendicular, we also know the angle of reflection.

This rule holds good, not only in flat, but in all other kinds of surfaces, of whatever figure they be. And it may likewise be noted, that if the reflected ray be again reflected, and if the reflection of it be repeated to any number of times, the same rule obtains. You have only to consider, that if a reflected ray is to be again reflected, it is to be considered as an incident ray; so that nothing in philosophy is more easy to be conceived than the reflection of light.

Before I proceed to explain the *refraction* of light, I must acquaint the reader, that whatever light passes through, is called by opticians a *medium*. Thus, air is a medium; water, and glass are mediums, and so of other transparent substances. An optician has only to consider bodies as mediums of greater or less refractive density. Thus air is a rare medium, and refracts but little; water a denser, and refracts more; and glass is a medium, still denser.

While

While a ray of light passes through a medium of the same density, it goes on in a strait line. But if it passes out of that medium into another, whose refractive density is greater or less, it takes a new direction, or is bent into an angle, as will presently be seen.

Into any shallow upright vessel put a shilling; and retire to such a distance, as that you can just see the farther edge of the shilling, but no more. Let the vessel, the shilling, and your eye, remain in the same situation, while an assistant fills up the vessel with water, and the whole shilling will now become visible. The reason of this will be shewn by the following scheme. (Figure 2.)

Let V represent the vessel, S the shilling, and E the eye. R E will be the only one of the three rays, coming from three different points of the shilling, which will reach the eye while the vessel is empty, and therefore only the outermost edge of the shilling can be seen : the rays in this case coming in a right line from the shilling to the eye.

Let now the vessel be filled with water, and let r N be a ray, coming from the innermost edge of the shilling, it will pass on in a right

line to the surface of the water. But on its entrance into the air it will not continue its course in a right line, but will be bent or refracted, so as to arrive at the eye (e) in the direction of the dotted line Ne; and hence you have the reason why the whole shilling was seen in the latter case, and not in the former; for if the inner edge is seen, the whole shilling must in course be visible. So likewise a strait stick put partly into water appears to be bent. And objects appear through a prism higher or lower than they really are.

I shewed before, that the angle of reflection is equal to the angle of incidence. But with regard to refraction, the case is otherwise, as you will find by the two following rules.

1. When the refraction is made out of a denser into a rarer medium, the angle of refraction is *greater* than the angle of incidence; that is, the ray is refracted *from* the perpendicular.

2. But when the refraction is made out of a rarer medium into a denser, the angle of refraction is *less* than the angle of incidence; or the ray is refracted *towards* the perpendicular.

To explain the first of these laws, let RS (fig. 3.) be a ray passing through the water in a right line,

line, till it arrives at S, draw Pp perpendicular to that point of the surface ; and as the refraction is out of water, a denser medium, into air, a rarer, it must be *from* the perpendicular. The ray therefore, instead of going on in a right line RS, will be bent into the direction Sr, and therefore the angle of refraction rSp is *greater* than the angle of incidence RSp.

To explain the second law, let RS (fig. 4.) be a ray passing through air in a right line to S. Pp is the perpendicular to that point of the surface. And as the refraction is to be made out of air, a rarer, into water, a denser medium, it will be *towards* the perpendicular. The ray therefore, instead of passing on in a right line RS, will be turned into the direction Sr, so that the angle of refraction rSp will be less than the angle of incidence RSp.

These cases, being only the reverse of each other, are perfectly easy to be conceived. And the rules hold good, as in reflection, whatever be the figure of the medium's surface. When therefore the angle of incidence is great, the angle of refraction will also be great; when small, the angle of refraction will likewise be small. And when the angle of incidence is nothing (that is, when the ray moves on to the surface of the body in the direction of the perpendicular)

the angle of refraction will be nothing; that is, the ray will continue to pass on in a right line, as if in the same medium: in like manner as when in reflection, the angle of incidence is nothing, the ray is reflected back into the line of its incidence.

As in reflection, the angle is always equal to that of incidence, so there is a constant or invariable proportion between the angles of incidence and refraction, with the same mediums; or, to speak more properly, between the sines of those angles. For an angle may be measured by letting fall a perpendicular from a given point in one of the lines, by which it is formed upon the other: this perpendicular line is called the sine of the angle; and in order to determine the ratio between the sines of different angles, no other caution is necessary than that the assumed points from which the perpendiculars are let fall be equally distant from the center or point of incidence. Thus it is found, that the sine of the angle of refraction out of air into water is to the sine of the angle of incidence always as three to four. But in different mediums the proportions are different, according to their refractive density. For example, the proportion of the sines of the angles of incidence and refraction out of air into glass, is as seventeen to eleven; and other mediums have other fixed proportions.

Having

Having thus explained the laws of reflection and refraction of light, I shall now proceed to the application of them; and also to the consideration of such other particulars as may be necessary to the understanding of the doctrine of vision.

Whatever is seen or beheld by the eye, is called by opticians an *object*. Thus, an arrow is an object; a bird is an object; a wall, the sky, the ground, &c. are objects.

The surface of an object is considered by opticians as made up of a vast number of very minute points placed close to each other; from every one of which points rays of light issue in every direction. If you single out one of these points, and imagine it to remain alone; or if you suppose that point only to be illuminated by the rays of light, it may be represented by figure 5th. p is the point, and the lines proceeding from it are rays of light. Of course, in whatever position the eye be placed, whether at A, B, C, &c. the point will be visible, rays being alike reflected from it to every part.

Now, let L represent a convex lens, or common burning-glass. Let it be placed before the point p, and as the glass is transparent, the

L 4

rays

rays will pass out of the air into the glass, and out of the glass again into the air beyond it, and then strait on. But as glass is a denser medium than air, it will refract the rays at their entrance into it, and the air beyond will again refract them in a contrary manner, in their passage into it from the other side of the glass, as may be gathered from what has been said of refraction. To represent this the more clearly, let p in the 6th figure be the point, L the lens, and p S one of the outermost rays that falls on that lens. P S will be the perpendicular to the point of the surface on which the ray falls. As glass is a denser medium than air, the angle of refraction will be less than the angle of incidence, and therefore the ray will be turned out of its right-lined direction, and go on in a strait line to n. It is now to pass out of the glass into the air. T n is the perpendicular to that point of the surface ; and as the refraction is to be out of a denser into a rarer medium, the angle of refraction must be greater than the angle of incidence, and therefore the ray will be turned from T, and in course it will go on in the direction of n x. Now it is obvious, that the ray p O must be refracted in the same manner as the ray p S. The two rays will therefore meet at x ; and if we suppose a number of intermediate rays issuing from the point p, they will all be refracted by.

by the glass in such a manner, as that their angles of incidence shall be to the angles of refraction, as seventeen to eleven, and they will all be again refracted by the air in passing out of the glass, in such a manner as that their angles of incidence shall be to their angles of refraction as eleven to seventeen, so that they will all meet at the point x; they will cross each other at that point, and then go strait on, forming the angle n x p.

Now, if a paper be placed at x, so that the rays may fall on it, they will paint the image or picture of the point p on that paper.

Instead of one, imagine three points, A, B, C, at a convenient distance from each other, and let the lens be placed before them, as represented in the seventh figure. The rays flowing from each point, will, after refraction in the manner before described, form each their respective images c, b, a, on a paper placed behind the lens, as you may also prove by experiment; but the images you see are inverted, or in a contrary order to that of their originals, the image of A, which is uppermost, being below, and the image of C, which is undermost, being above,

To

To make this more plain, place the convex lens before a candle, and at a proper distance on the other side, hold a piece of paper; you will find the image of the candle very exactly painted on this latter, but in an inverted position, or upside-down, just as is represented in the figures; and if you imagine the whole surface of the candle to be made up of luminous points, and the rays from each point to be refracted in the manner of those three which are here delineated, you will have the whole experiment, with its very curious reasons, clearly before you.

But this is not the principal inference which was meant to be drawn from this experiment. You will find, that by holding the paper nearer to the lens, the image of the candle becomes less clear or distinct, till at length its figure is quite lost; and the like happens by removing the paper beyond the proper distance. If you look in figure 6, you will perceive that the image of the point p can only be painted in its proper dimensions, where the rays meet at x. If the paper be held nearer, or removed further from the lens, as at k or l, not a point, but a spot will be painted on it by the rays; and the spot will be greater according as the paper is removed either way from the point;

the

the point or place where the rays meet and cross is called the *focus*. So in figure 7, when the paper is in the focus of the rays, each point of the candle is painted in its proper size and situation with respect to the others, as in the original ; and therefore the whole image formed of those points appears distinct, or rightly defined. But if the paper be supposed to be removed out of that focus, either towards or from the glass, the images of the points of the object will be enlarged, and run into one another, the picture formed of them will of course become indistinct or confused, and that so much the more as the paper is further removed from the focus, till at length it is no longer distinguishable.

Thus much being premised concerning the images of objects, we may proceed to the doctrine of vision.

In the eye are contained three humours, the aqueous, crystalline, and vitreous, separated from each other by proper coats or membranes. A (fig. 8.) represents the aqueous, or foremost, C the crystalline, which is in the middle, and V the vitreous, which is behind, and fills up all the back part of the eye ; p p is the pupil or hole through which the rays pass, and R, R, R, is the retina, placed behind all the humours, and which is the proper organ of vision. For the rays

rays of light, by striking against that membrane cause vision, in like manner as any thing struck against the skin causeth feeling. Thus also, if you strike the corner of either eye with your finger, you see a spot of light; the stroke of the finger being conveyed by the humours of the eye to the retina. Also, if the eye be violently struck, light is seen, as pain is felt from striking any part of the body, in which is the sense of feeling.

The three humours of the eye are to be considered as so many mediums. The aqueous is the rarest, the crystalline the densest, and the vitreous between both.

If a ray of light, as  $rR$ , falls perpendicularly on the eye, it passes strait on the retina, without refraction; for reasons which have been already given.

But if a ray enters the eye in any other direction, it will be refracted by the several humours, in the following manner.

Let  $Rt$  be a ray passing through the air to the eye, so as to fall on the cornea at  $t$ ; and as the aqueous humour is denser than air, the refraction must be made towards the perpendicular, as has already been explained; the ray therefore will pass on to the surface of the crystalline hu-

mour

mour in the direction of tn. The crystalline is denser than the aqueous and vitreous humours, and therefore the ray will, by the refraction, be deflected towards the axis of the crystalline, upon the principle of convex lenses, and will at length fall at R on the retina.

Other rays may be imagined issuing from the same point with the ray rR, so as to occupy the whole width of the pupil p, p, and then they will all be refracted in like manner, so as to meet in the same point of the retina; and the image of the point r, from whence the rays flow, will then be painted on the retina, in the same manner as the image of the point p in figure 6 was painted on the paper by means of the lens.

Imagine three such points, viz. O, r, B, with rays proceeding from each of them to the eye, analogous to what was before described with respect to the lens. The rays after refraction will meet on the retina in three points, b, R, o, in an inverted situation with respect to their originals, the image of the upper one being lowest, and that of the lower one highest; and by the same reason, if you place an arrow before the eye, the image thereof will be painted in an inverted position with respect to the arrow itself, as was shewn of the lens. From hence you  
will

will also understand, that the images of all objects seen by the eye are painted on the retina in a direct contrary position to the objects themselves; the upper parts of those objects being painted lowermost in the retina, their right sides on the left in the retinæ, and the like of other parts.

It may be asked, "How comes it that objects are seen in their proper position, seeing that their images are inverted in the eye?" To this it may be answered, that it is not the eye itself that sees, but the fibres of the optic nerve which are expanded into, and form the essential part of the retina, convey the impression which they receive from the impulse of the rays, to the sensory or seat of the mind, at the origin of those nerves in the brain. As a proof of this, if the optic nerve be compressed, so that its communication with the brain is hindered, objects are not seen, though their images are painted on the retina as usual. Thus also, if by leaning the head on the hand, with the elbow resting on a table, or by throwing one leg over another, certain nerves are compressed, the parts which they serve lose their sense of feeling, as every one must have observed; which also shows, that it is not the organ of sense, but the mind seated at the origin of the nerves in the brain, which perceives. The  
fibres

fibres of the optic nerve, when they arrive at the sensory, are disposed in a contrary situation to what they are in the eye, those fibres which are on any one side of the retina going to the contrary side of the sensory; and hence objects are painted in the sensory in their true position.

You may form a crude idea of it by the 9th figure, where A, B, C, represents the retina of the eye, c, b, a, that of the sensory, the fibres Ac, Bb, Ca, of the optic nerve, and of course the arrow a, b, c, being in a contrary position to what they are in the sensory; and even the figure of the retina is also inverted; for its concavity is outwards in the eye, but inwards in the sensory; and the concavity is *towards*, not *from* the perceiving principle, as I have elsewhere shewn \*; for, by pressing the center of the eye, so as to excite the whole retina, I found that the luminous appearance caused thereby was concave, but that the concavity looked *towards* me, which again proves that it is not in the eye, but in the sensory that the images of objects are perceived; for the concavity of the retina of the eye looks the direct contrary way. There being an insensible spot in the retina, and no dark spot in an object viewed answerable thereto, is another argument that it is not the

\* In Philosophical Observations on the Senses, &c.

eye,

eye, but the mind at the end of the nerves in the brain that sees the object.

But to return to our subject. It was shewn before that the image of the candle refracted by the convex lens was not distinct, except the paper was held at a certain distance from the lens; and that the reason was, that the paper must be held in the focus of the rays, or just where the rays meet in points, or pencils, if I may so call them, before they cross each other: for, that if the paper was removed from that focus either way, the image became confused. The cause of this confusion I also fully explained; but, previous to the application of it to vision, it will be necessary to pursue the subject a little farther.

If the lens be held at a certain distance from the candle, and the paper at a certain distance from the lens, the image on the paper will be distinct. If now you keep the paper at the same distance from the lens, and bring the candle nearer, its image on the paper will begin to be less distinct, and its confusion will be greater as the candle is brought nearer to the lens. Also, if the candle be returned to its first distance, and then removed the contrary way, or farther from the lens, the image will become more and more confused, in like manner as when it was brought nearer. The reason of this is,

that

Plate II. to jace p. 101.

Fig. 10.

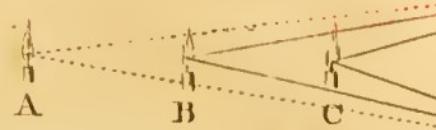


Fig. 12.

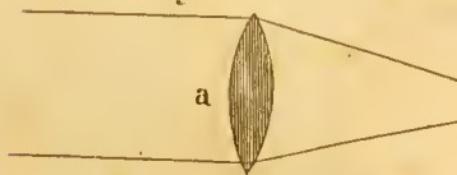


Fig. 10.

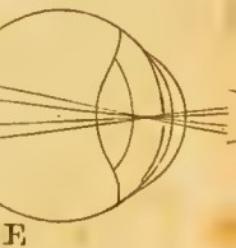
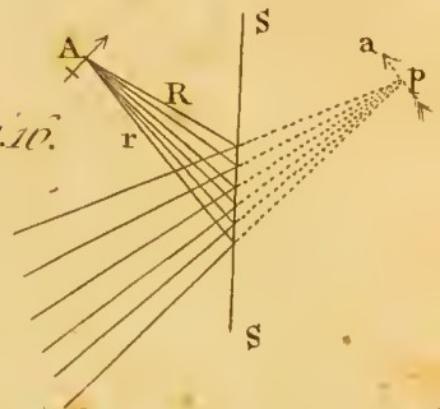
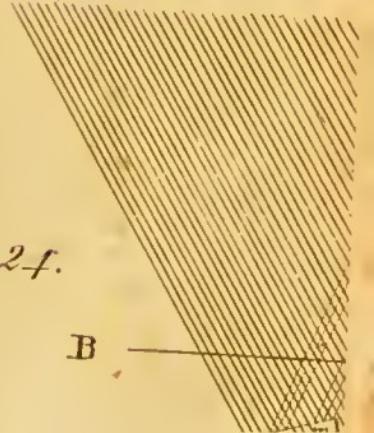


Fig. 24.

B



P. H. le pice p. 10.

Fig. 10.

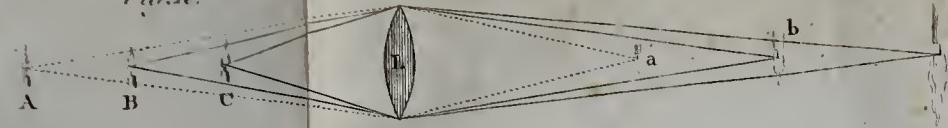


Fig. 12.

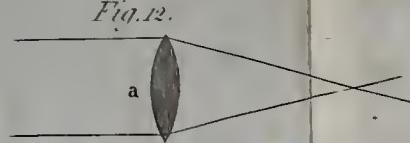


Fig. 13.

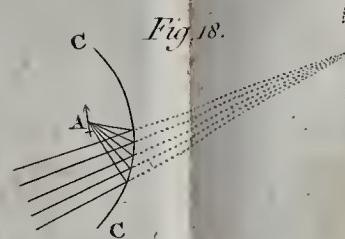
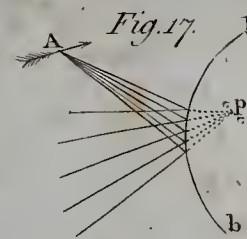
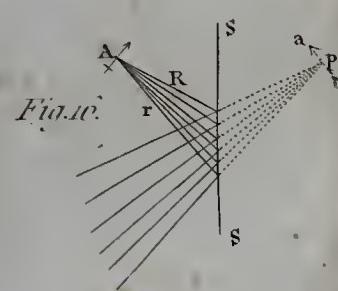
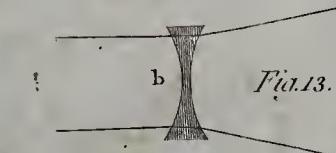


Fig. 21.

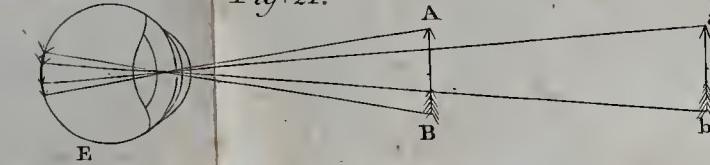


Fig. 24.

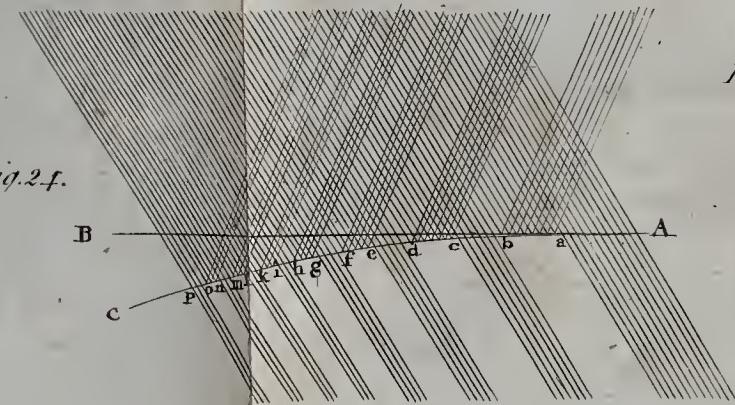


Fig. 25.



Fig. 22.

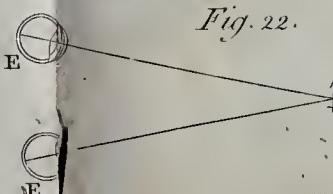


Fig. 26.

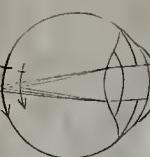
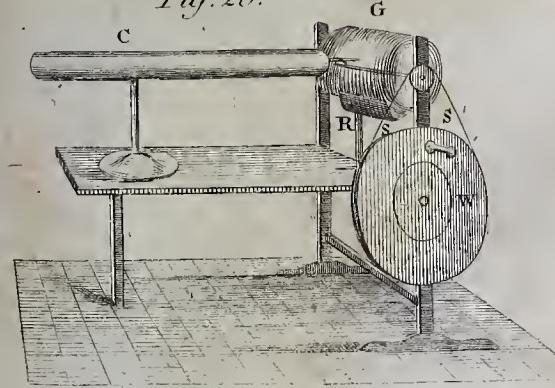


Fig. 11.



Fig. 15.

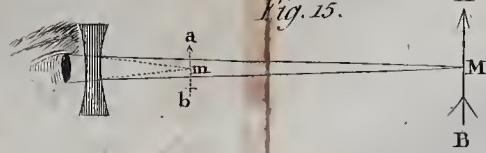


Fig. 20.

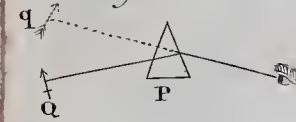


Fig. 23.

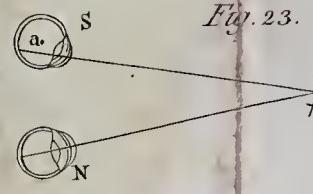


Fig. 27.



that when the candle is nearer to the lens, the focus falls at a greater distance than when it is removed farther off. Let L be the lens (fig. 10.) and A, B, C, the candle at three different distances from it; the focus in these cases, will fall at a, b, and c, respectively, as you will find by tracing the refractions of the rays from these several distances, according to the foregoing rules; and consequently the distance of the paper from the lens, in order that the image may be painted distinct, must be varied, according to the distance of the object from the lens. If you look on the figure, you will also find that the angle which the rays make with the lens, is greater according as the distance of the object is less, and the focus of the rays is nearer to the lens according as that angle is less. The distance of the focus therefore depends on the angle which the rays, issuing from a point of an object, makes with the lens.

Now for the same reason that the focus varied its distance from the lens, according to the distance of the candle from it, the focus of the rays refracted by the eye must also be nearer to, or farther from, the crystalline humour (which is likewise called a lens) according to the distance of the object from the eye: for when the object is at a greater distance, the focus must be nearer; and when the object is less remote, the focus must be more distant. But yet in order to see objects distinctly or clearly, the retina as well as the

paper in the above experiments, must be exactly in the focus of the rays ; for if this does not happen, it is obvious that the pictures of those objects cannot be formed on it distinct ; and yet distinct vision depends on the perfection of the images of the objects looked at, on the retina. But if the arrow A, fig. 11, be moved nearer to the eye, or farther from it, you see that in the latter case the focus does not reach the retina, and in the former it would fall beyond it ; consequently, as the image in either of these cases would be confused, the arrow could not be distinctly seen ; but it is well known that we see an object equally well in proportion to its apparent size, whether its distance from the eye be greater or less. Thus, the arrow when at two yards distance, does not appear more confused than when only at one. The reason of this difference is, that the glass lens retains the same figure or shape, whatever be the distance of the object, and therefore, according to the laws of refraction, the focal distance must vary as above. But the eye has the wonderful faculty of adapting its figure to the distance of the object, so as always to have the retina in the focus of the rays, and this is effected by means of the crystalline humour, which serves the purpose of a convex lens. When the object is at a distance, and the focus would fall short of the retina, the crystalline lens forms itself into a less convex figure, and therefore refracts the rays less ; so that the focus

focus is made to fall more distant than it would naturally do. But when the object is near, and the focus would naturally fall beyond the retina, the crystalline lens becomes more convex, so as to refract the rays more; and bring the focus nearer, so that whatever be the distance of the object, the focus, by means of this admirable contrivance, always falls on the retina; and in course the object at whatever distance; is seen distinct.

The use of a convex lens is to make rays converge or approach nearer to each other, as hath been shewn; and the greater its convexity, the more does it encrease their convergency: But a concave lens, on the contrary, causeth rays to diverge or recede from each other, and the more so, as the concavity is greater. The figures 12 and 13 represent such lenses; the rays falling on them in parallel directions, are turned from their parallel, to a diverging tendency, by the concave lens *b*, and to a converging tendency, by the convex lens *a*. The reasons of this difference will easily be understood by tracing the refraction of a ray falling obliquely on each of these glasses, according to the rules already laid down.

People advanced in years are generally obliged to use spectacles; of spectacles however, there are two kinds, those made of *concave*; and those made

of *convex* glass lenses. When the eye becomes old, it shrinks or loses part of its plumpness or convexity; so that it cannot, even with the assistance of the change of figure of the crystalline humour, sufficiently refract the rays, and therefore they will converge to points beyond the retina. A convex lens encreases the convergency of the rays, and therefore if placed before the eye, will cause the focus to fall nearer to the crystalline humour. The spectacles used by aged people are therefore made of convex lenses. But the eyes of some are more withered than those of others, and those in whom this defect is greatest, require lenses of a more convex figure in order to make the rays converge to the retina. Hence the reason why the same spectacles will not serve for different people; and we find that opticians number their spectacles according to the degrees of their convexity.

There are likewise many people who are *near-sighted*, the defect of whose eyes is directly the reverse of those just discoursed of. For they are too plump or convex, so that they converge the rays before they arrive at the retina. Now the concave lens, by encreasing the divergency of the rays before they enter the eye, prevents their being converged so soon as before; and hence according as the eyes are more plump, spectacles of greater concavity are required, in order that the foci of the rays may be made to fall on the retina;

retina; which, as hath already been shewn, is necessary to distinct vision. As the eye naturally grows flatter by age, the sight of these people mend as they become older, and therefore they are said to have the most lasting eyes.

Having thus given a general idea of vision, I shall now proceed to explain some of the particular phenomena thereof.

You may have observed, that objects appear through convex lenses at different distances from what they do to the naked eye. Thus, the object  $L$ , fig. 14, when seen by the naked eye, appears at  $L$ ; but if a convex lens be placed before the eye, the rays, after refraction, if they were continued on in strait lines, would not meet at  $L$ , but at the point  $l$  beyond it, at which place the object will appear; for you may gather from what has been said before, that "*an object always appears in that place to which the rays would converge, or from which they would diverge, in falling on the eye.*" It has already been shewn, that according as an object is more distant, the angle which the rays issuing from a point thereof, form with the eye is less; now the eye judges of the distance according to that angle. As the apparent distance therefore depends on that angle, it follows that the eye must form the same judgment of the distance of the object  $l$ , whether the rays *really* flow

M 3 . . . . . from

from that distance, or only *seem* to do so; and hence we have the cause of many curious deceptions of vision. Thus, a concave lens (fig. 15.) makes an object appear nearer, because by diverging the rays, it makes them flow as from the point  $m$ , less distant than  $M$ , the point from whence they diverged before.

If an object behind you be seen by reflection from a common, or plain mirror, it does not appear as upon the surface of the glass, from whence the rays really come, but as far beyond that surface as the object itself is distant from it. Let  $SS$ , (fig. 16.) be the surface of the mirror,  $A$  the object, and  $Rr$ , rays flowing from a point of that object to the glass from whence they are reflected to the eye. If the rays were continued from the eye, according to the dotted lines, they would meet in the point  $p$ , and therefore the object must appear as at  $a$ , as we find to be the case.

If the surface of the mirror be not plane, but convex, as  $bb$ , (fig. 17.) the rays will be more diverged after reflection from the glass to the eye, and therefore if continued, would meet in a point  $p$ , nearer to the eye than in the last case, and hence the object would seem to be nearer.

On the contrary, if the surface be concave, as  $CC$ , (fig. 18.) the rays will be rendered less diverging as they flow from the glass, than by the

plane mirror, and therefore the point p, at which they would meet, would be more distant; so that the object would appear more remote. But if the concavity be so great as to render the rays converging, as they flow from it to the eye, the point will be before the surface as at p, fig. 19, and therefore the object will appear less distant than the glass.

If the object Q, (fig. 20.) be viewed through a glass prism P, it will not appear at Q, but at q, the point to which the rays after refraction would converge. So the shilling in fig. 2. appeared to be removed out of its place. Hence also a stick partly placed in water does not appear strait, as before, but bent; and other instances of the changes of place, or distance of objects, by reflection and refraction, may be understood by means of this rule.

You may likewise have remarked, that objects when seen in some cases of reflection and refraction, appear to be bigger or less than naturally. Thus, an object seen through a convex lens appears bigger; and through a concave lens less. You will understand the reason of this, by observing that the points of which their images are composed, are by the refraction or reflection, removed further from, or brought nearer to each other than before. Thus, the points of the arrow a b, in fig. 14, are by means of the convex

lens, removed farther from each other, than in A B, and by the concave lens in figure 15, brought nearer to each other than in A B, and of course the object must appear larger in the former, and less in the latter case, than to the naked eye. For like reasons a concave mirror makes objects appear larger, and a convex one smaller than naturally. On these principles the construction of telescopes, and other magnifying glasses depend.

The image of the same object in the eye is less, according as the distance is greater. Thus, let E, fig. 21, be the eye, A B an object at a certain distance from the eye, and a b, the same object, at twice that distance; the image in the retina in the latter case is but half the length of that in the former. You may prove this by placing two sticks of equal lengths, one at a yard, the other at two yards distance from the eye, so that the lower ends of them may appear parallel, and you will find that the nearer one has twice the apparent length of the farther. The reason of this is, that the angle formed with the eye by the rays proceeding from A B is greater than that formed by the rays from a b. The angle which an object forms with the eye is called the *visual angle*; this angle is diminished as the same object is removed to a greater distance, and also when viewed through a concave lens, or by reflection from a convex mirror; on the contrary, in proportion

as

It must be understood then, that every part of the retina of one eye has a corresponding part in the other; so that when the image of the same object falls, in the same manner, upon the answerable parts of both eyes, only one object is perceived, as if the image had fallen upon one eye only. Thus, if you look at a shilling, you see it with both eyes at once, as you may prove by shutting one of them, and yet with both eyes you see only one shilling.

It was shewn before that vision is not made in the eye, but by the nervous expansion in the *sensory*. If you imagine each of the fibres of the optic nerve, of which this is formed, to be double, or composed of two, one of which goes to the answerable part of each eye, you will be able to form a very clear idea of this phenomenon, and that this is the case, appears by the following experiment. Look at any object, suppose the flame of a candle, steadfastly with both eyes, you behold it single; but force one of your eyes out of its position with your finger, the object is no longer seen single, but two flames are beheld instead of one; and the more the eye is forced out of its direction, the more distant from each other will the two flames appear. And this ought to happen, according to the theory; for the image of the object in one eye, can now no longer fall on the corresponding part of the other; and this variation must needs be greater, accord-

ing

ing as the eye is forced more aside, as appears by experiment to be the case.

If you fix any object against a wall, or otherwise, and let a person stand very near it, looking at it steadfastly, so as to view it single, and if then he removes backward, still looking at the object, you will find that when he was near it, his eyes were turned more towards each other, than when he was at a distance, and that his eyes as he retired, continually receded from each other. Now in order to see an object well, its image must fall on the centre or middle part of the retina. If any person looks at an object with one eye, you will find that he turns his eye directly towards it; for though it may be seen otherwise, yet it is not seen distinct or clear, as will be found upon trial. Now if you imagine a right line perpendicular to the centre of the retina, that right line will pass directly through the center of the eye to the object beheld, and this line is called by opticians the *optic axis*. When you see an object singly with both eyes, the two optic axes meet in the object; or in other words "the image of that object is then painted exactly on the corresponding parts of the centres of both eyes." Consequently when the object is near, the optic axes must meet near, or form a greater angle, for which purpose the eyes must be turned more towards each other. But when the object is remote, the axes must meet at a greater

greater distance, and therefore the eyes must be turned more away from each other as the 22d figure will also more fully explain, for unless the optic axes meet in the object, the images of the object are not painted on the corresponding parts of both eyes, and of course the object will not be viewed single; the contrary of which always happens when the axes meet in the object. We have therefore, you find, several ways of judging of the distances of objects by vision. 1. By both eyes, according as they are turned more away from each other to view them singly; 2. By each eye, according as it must alter its figure for throwing the image of the object distinctly on the retina; and, 3. By the smallness and indistinctness with which objects of a known size appear. Thus, distant hills appear smaller and more obscured by mists, &c. than when they are near, and thence are known to be remote; and there are also other auxiliary methods of judging of the distances of objects; as by comparison with others whose distances are better known, and the like.

In some people we find that the eyes are naturally distorted, or they *squint*, and yet they see objects singly as well as others who have not that deformity. In these people, the globe of one of the eyes is turned awry with respect to the retina, so that the optic axis coming from the center of the retina, does not pass through the center

center of the cornea, or globe of the eye, as happens when the eye is perfect; and therefore when the images fall on the corresponding parts of both retinæ, the eyes will not appear to an observer to look the same way. Thus, in fig. 23. *S* is the squinting eye, *N* the natural one. The optic axis of *S* does not pass through *a*, the axis of the globe, but on one side of it, and of course in order that the images may fall on the corresponding parts of both retinæ, that eye must be turned so as to appear distorted. In some cases however, these people only see objects with the sound eye, the image in the other falling on the insensible spot at the entrance of the optic nerve, already described.

If the retina loses its sensibility, as sometimes happens from an oppression of the optic nerve, or other cause, no objects will be seen, though their images are thrown on the retina as usual, or in other words a total blindness will take place; and if the sensibility be lost in part, vision will be less strong in proportion. Also if any particular part of the retina should happen to lose its sensibility, either wholly or in part, a partial blindness, or defect of sight, will ensue; the other parts of the retina enjoying their power of vision as usual.

If either of the coats or humours of the eye becomes totally opaque, vision will also be lost, because

because no rays can then pass to the retina. And if the opacity be imperfect, the sight will become more obscure in proportion. Sometimes the crystalline humour becomes opaque, but if it be removed by extraction, the sight will be restored, except that a convex glass lens is required to be used, to supply the place of the humour lost. This is not requisite when the aqueous humour is extracted, as that humour soon regenerates; which the crystalline does not.

In some cases the opacity is not total, but only partial; and sometimes there is a difficulty of knowing in what part of the eye the opacity exists. The doctrine of vision already explained will assist in ascertaining it.

When large particles float in the aqueous humour, gnats, flies, webs, and the like, seem to float before the eyes.

When a person has the jaundice, and the eye becomes tinged yellow, the objects seen appear also to be tinged with that colour.

#### OF THE COLOURS OF LIGHT.

Into such an hole of a window-shutter as was described at the beginning of this chapter, let a beam of the sun's light be admitted, and it will paint a round white spot on the opposite wall.

But

But if the beam passes through a glass prism, so that it may be properly refracted, the round spot will be changed into an oblong one ; and instead of being white, as before, it will appear of various colours ; its lower part will be red, its upper part violet, and the intermediate parts of other colours. If other prisms are used so as to refract the beam again sufficiently, the colours will be found to lie in the following order ; *red, orange, yellow, green, blue, indigo, violet*, the red running gradually through all its shades into orange ; the orange into yellow, and the others into those next following, till we come to the deepest violet. From whence it is plain that light consists of rays of various sorts ; some of which are more refracted by the prism than others, the red making rays least, the violet most, and the others intermediate to those according as they stand in the above series.

The rays of light therefore are not alike, for it appears that some of them are more, others less easily refracted by the prism. These different rays have also the property of causing different colours in the eye, the least refrangible ones causing red, the most refrangible violet, and the others other colours according to the order described above ; and all the colours in the universe depend on this diversity of the rays. When all the rays are mixed together they cause a white colour, and hence the light of

of the sun, which is composed of all sorts of rays, appears white. If the blue and yellow-making rays are mixed together they cause a green. If red and violet ones are thus mixed they cause a purple. And mixtures of other rays produce other colours. The colours of all bodies depend on the kind of rays which they reflect to the eye. Thus paper reflects all the rays equally, and thence appears white. But if we put a slip of paper in the red part of the *spectrum* (for so the long spot of coloured light made by the refraction of the prism is called by opticians) we find that it no longer appears white, but red, because now it reflects only the red-making rays to the eye. If we place it in the blue part of the spectrum, it appears blue, by reason that it now reflects only the blue-making rays. Sealing-wax naturally appears red, by reason that it reflects most copiously the red-making rays, but if it be held in the blue part of the spectrum, it appears no longer red, but blue; and the like may be observed of other bodies. Painters knew part of this doctrine by practice, long before the theory was found out. Thus by mixing a blue and yellow colour together, they compound a green. Red and blue, a purple; and by mixing several compound colours, which, together, contain all the original colours mentioned above, in proper proportions, they form a white, and the like. That is, those mixtures reflect the rays producing those respective

N                      colours

colours to the eye, and thence appear to us of those colours.

If water be made tenacious with soap, and then blown into a bubble, it is well known that after a while a variety of colours will appear. These colours depend on the thickness of the coat of the bubble, and vary continually as the thickness decreases.

To explain the reason of this, let *A*, *B*, *C*, (fig. 24.) represent a thin plate of air between two glasses, the upper one *AB* being plane, and the lower one convex; and let the lines inclining from the right to the left represent the red-making, or least refrangible rays, falling, without any others, on the plate of air. It will be found that from the concourse of the glasses *A*, to *a*, the rays will pass through that plate, or be transmitted; but from *a* to *b* they will be reflected. From *b* to *c* they will be transmitted; but from *c* to *d* they will be reflected: and so on alternately, according to the thickness of the plate of air.

In like manner, if upon the bubble of water we throw only the red-making rays, the bubble will not become variously coloured, as is the case when rays of all sorts fall on it, but rings of red and black alternately will be seen. The red rings are caused by the rays reflected at those thicknesses of the bubble, the black ones arise because no rays are reflected at these thicknesses; and if the bubble be viewed on the contrary side,

or

or by the transmitted rays, those parts which by the reflected light looked red, will now appear black; and contrariwise.

When therefore the rays entered the air anywhere between *A* and *a*, they preserved their disposition to be transmitted till they arrived at the further surface of the air, and therefore were transmitted. But when they entered the air at the thickness anywhere between *a* and *b*, they lost their disposition to be transmitted by the time that they arrived at the further surface of the plate, and therefore were not transmitted, but *reflected*. The like may be observed of the thicknesses *b*, *c*; *c*, *d*; *d*, *e*; &c. but the thickness *c d* being double that of *a b*, the rays must have had two fits or dispositions to be reflected in their passage through the latter thickness, and for the same reason they must have had two fits or dispositions to be transmitted during their passage through the thickness *b c*; and so in proportion for a greater thickness. From hence it appears, that the rays of light do not move on uniformly; but by fits, or starts; that if they arrive at the further surface of the plate in the progressive fit, they break through that surface and so are transmitted; but that if they arrive at that surface between these progressive fits, they are on the contrary reflected. This pulsatory motion of a ray of light is called the *vibration* of the ray.

The rays of light of all other colours move on in like manner by fits or starts, or have a like vibratory motion, but with this difference, that their vibrations are swifter; that is, they have a greater number of them in the same time, or in moving through the same space, than the red-making ones. The violet-making rays, for example, vibrate almost twice as swift as the red, that is, though they move on with the same velocity as the red, yet in moving through the same space they make almost twice the number of vibrations. Hence the violet rays begin to be reflected at a less distance from *A* than the red ones, at *x* for example; and begin to be again transmitted at a less distance than *b*, or even within *a*, and so on continually; and the times of vibration of the other rays, and of course the spaces or distances from *A*, at which they begin to be reflected and transmitted, are greater than those of the violet, in proportion as those rays are nearer to the red ones in the spectrum; that is, in the order of violet, indigo, blue, green, yellow, orange, and red. Agreeable to this theory we find that in the bubble of water on which all sorts of rays fall, the red in every order of the colours is outermost, and the violet inwards; the other colours lying between, according to the order of their reflection as above; so far at least, as from their mixture in so small a compass they can be distinguished from each other.

From:

From this curious theory we have the cause of the colours of bodies; the particles of which, according to their different sizes or thicknesses, reflect rays of different colours to the eye, on the same principle as these colours are exhibited by different thicknesses of the bubble. Sir Isaac Newton, to whose transcendent genius we are indebted for this theory, has even calculated the thicknesses of a bubble of water, and of the particles of bodies, requisite to their exhibiting the various colours.

From hence also we are furnished with the solution of a variety of phenomena in chemistry. If an acid be added to a blue vegetable infusion, as syrup of violets, it changes its colour to red. If an alcali be added to the same syrup, it alters the colour to green; which ariseth from hence, that the sizes or thicknesses of the colouring particles of the syrup are in these cases varied by the respective additions, so as to cause them to reflect rays of different colours. The particles of venous blood exhibit a deep red; but by exposure to air, and the consequent loss of their phlogiston to that fluid, their sizes or thicknesses are altered so as to reflect those rays which constitute scarlet. By mixing chemical liquids, 'tis well known that a variety of odd changes of colour succeed, which are easily accounted for by this theory. But for farther information in this curious doctrine the reader

is referred to the illustrious author just mentioned, and also to the ingenious Mr. Delaval's treatise on colours. I have only introduced thus much of it to explain the vibrations of the rays of light, the understanding of which will be necessary to what will be advanced in a future chapter relating to vision.

I have now gone through as much of the delightful science of optics as is necessary to the illustration of the doctrine of vision; with the following particular therefore, I shall close this chapter.

The refrangibility of the rays of light as above described is caused by the attracting power of the prism; and as the violet-making rays are most refracted, and the red-making ones least, it follows that the former are so constructed (whether by being composed of smaller particles, or otherwise,) as to be more easily drawn out of their right-lined direction.

When incombustible bodies are heated, it is well known that they shine, or emit light. They are then said to be ignited. Now the rays that are least refracted by bodies are most easily expelled in ignition; for bodies when heated, first shine with a red coloured light; and this argues that as the red-making rays are least attracted by the prism, so the particles of which they are composed

composed are retained by bodies with least force. As the heat encreases, the particles which constitute the more refrangible rays begin likewise to be expelled, and by their mixture with the others, the red colour of the body verges more towards white; and when the heat is sufficient, so as to expel all the particles equally alike, the colour must be white; hence the body is said to be *white hot*.

But the flames of phosphorus, of sulphur, and of some other bodies are not ignited, for if they were they would shine with a colour somewhere betwixt reddish, and white, for reasons just given. On the contrary, their colours are *blue*: their light therefore must be emitted on a different principle from that of ignition.

To understand the reason of this, suppose that either *the inflammable body*, or *the air*, contains a quantity of particles of light; and that in the process of combustion it is transferred from the one of those substances to the other. But that the quantity extricated from the one, is greater than the other can absorb. That therefore which is not absorbed will appear, or fly off, under the form of *light*.

As in ignition bodies retain the blue light most powerfully, and part most easily with the red, and other particles which compose the less

refrangible rays, so in combustion the absorbing substance will, for the same reason, most easily acquire the particles which compose the less refrangible rays; with which being first saturated, the others remain behind as the superabundant particles above spoken of, to be driven off in the form of *light*. The flame therefore must appear of a *blue* colour, as we find by experience to be the case.

From hence therefore it appears that light existed in a latent state, either in the air, or the inflammable body, as was mentioned before. For that part of it which was not absorbed, assumed the form of the more refrangible or blue-making rays; and of course, if that which was absorbed had also resumed its luminous state, it would have constituted those rays which are less refrangible \*.

It may be observed, that those flames which are hotter than the above, as of tallow, oil, &c. are also *ignited*; and therefore their colours are compounds of the lights of ignition and of combustion.

The blue light of the *latter* may be seen at the bottom of the flame. For the particles take some

\* I suspect that what I call the light of combustion comes from the inflammable body; and that it was *chemically combined* therewith, (as the fire or heat was with the air) constituting its *phlogiston*.

some little time to become red hot ; and therefore they do not begin to emit the light of ignition till they have ascended some little way up the vapour. When the flame is sufficiently minute, nothing but this blue light is seen.

## C H A P T E R II.

O F

## S O U N D.

SOUND is demonstrated by philosophers to depend on the air : for if a bell be struck in a vessel exhausted of air, it yields no sound.

I have already shewn that the particles of air are elastic, or that they *repel* one another, and therefore are kept at a distance from each.

If a musical string, stretched sufficiently tight, be drawn into a curved figure, and then let go, it causeth a sound.

The sound is occasioned by the vibration of the string, or motion of it continually to and fro, in the manner of a pendulum, till it returns to a state of rest.

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As the string moves to and fro, it drives the particles of air contiguous, a little forward. These particles urge on those next them, those again others, and so on to a distance, till the force of the stroke is spent. Hence

1. The effect of one stroke or pulse will be propagated to a greater distance, according as that pulse is stronger. Thus loud sounds are heard at a greater distance than weak ones.

2. The effect of a pulse or stroke, is propagated through the air in *time*, and the time is greater according to the distance. For it must take up twice the time for a pulse to be propagated two miles than one. Hence when we are at a distance we see an object struck, or view the flash of a gun, some time before we hear the sound, and this difference is greater according as we are at a greater distance. Sound moves about  $11\frac{1}{2}$  feet in a second; and all sounds, whether strong or weak, move with equal swiftness; the particles of air, like a pendulum, vibrating in equal times, whether the latitude of that vibration be greater or less.

3. For while the string is going back after the stroke, the particles of air, which it immediately impelled, return to their former places, or rather beyond, in the manner of a pendulum; and the particles beyond these do the same in a continual

continual succession, according to their distance; but when the string returns, it again drives them forward as before, and so on alternately, as long as the string continues to vibrate. This agitation is propagated alike on every side, from the string through the air.

This reasoning however, is somewhat abstruse. In order therefore to form a clearer idea of this matter, drop a small round pebble into a pond of water; immediately a ring, or circle will be seen, propagated from that point, and swelling, or extending itself to a distance. This ring is succeeded by another, that again by another, and so continually, till the effect ceases. If instead of rings, or circles, hollow spheres be imagined to flow in like manner, from the vibrating string, it will give a proper idea of the manner in which sounds are propagated through the air. But as air is above 800 times rarer than water, the waves or pulses of air, move above 800 times as fast as those of water. The sounds of all other bodies are caused by like vibrations of the bodies, and those vibrations cause spherical waves or pulses in the air, in the same manner as hath been described of musical strings.

Some sounds are more acute or shrill; others lower, or more grave. Thus, a woman sings in an high, shrill voice, but a man much deeper; or the difference may be still better illustrated,  
by

by means of an harpsichord or organ. The treble keys, or those on the right hand, cause higher notes; and the bass keys, or those on the left, notes which are deeper; and there is a regular gradation of them, from the highest, or most shrill, to the lowest, or most grave.

The strings which yield the high notes are shorter, smaller, and drawn tighter than those which give the low ones; the vibrations of the deepest bass strings are so slow that they may be seen by the eye. They are swifter as we approach towards the treble strings, and in these latter, the vibrations are so swift, that the eye can no longer distinguish them. The sounds therefore are higher in note, according to the swiftness of the vibrations of the strings; and the like may be observed of the sounds of other bodies. Now as every vibration of the string causeth a wave or pulse in the air, it follows, that the acuteness of the sound is greater, according as these pulses, or waves succeed each other more swiftly on the ear; or according as there are a greater number of them in a given time. Pulses which are twice as swift as others, cause sounds which are octaves. Pulses which are four times as swift as others, cause double octaves, and so on.

Two sounds whose pulses succeed each other, equally swift, are *unisons*; their pulses happening

at the same instant of time, and hence an unison is the most perfect concord in music.

Two sounds whose pulses are in swiftness as two to one, are octaves. Their pulses meet at every second vibration of the swiftest, and at every vibration of the slowest. This therefore is the second concord in music.

Two sounds whose pulses are as three to two, meet at every second of the slowest, and at every third of the swiftest. This concord is called a *fifth*, and is the third and last perfect concord.

Sounds whose pulses are as four to three, as five to four, as six to five, &c. are less harmonious when sounded together, than the concords, and are therefore called *discords*, and they are more discordant, according as their pulses meet less frequently. They are used in music to give a variety to the concords, which would otherwise be too luscious for the ear.

On this coincidence of pulses depends another curious property of sounds. If two musical strings are drawn into unison with each other, and one of them be put into vibration, it will cause the other also to vibrate, so as to yield a sound. This second string is put into vibration by the pulses excited in the air by the first, which pulses correspond with the times of vibration

vibration of this second string; the sound of a flute, the voice, &c: in unison with a string, would equally put it into vibration.

A string will also be affected in this manner, though in a less eminent degree, by a sound which is an octave to it; and in a degree still less by a sound which is a fifth. But as the coincidence of the pulses is not at every vibration, the effect, especially in the latter case, is not considerable; and therefore unisons only are usually considered in this view.

I shewed before, that light moves on in a right line; and when the ear is so situated, that the sound may come to it, directly from the sonorous body through the air, the sound is heard directly in that situation. If four sonorous bodies are placed east, west, north, and south, and no obstacle intervenes, their sounds are heard directly in the lines of their respective situations.

I explained likewise that light is reflected in an angle equal to that of its incidence, and the same happens with sound. If a sound coming from a body be reflected by a wall, or hill beyond us, the original and reflected sounds are both heard in their respective situations. Echoes are sounds reflected according to this law.

There

There is, however, this difference between light and sound, that an object cannot be seen out of the right line, or in the shade. But sound being made, not by the emission of particles in right lines, like light, but by pression, or propagation through a medium, or fluid, which is on every side, sounds may be heard out of the right line, or when the bodies yielding them are not seen, only they are heard to less advantage. Thus an echo is heard most perfectly at the place where the sound is reflected in the angle equal to that of its incidence. But it may also be heard in other places.

When sound passes through an hollow tube of a conical form, it is stronger, or louder at its exit through the smaller aperture, than it was at its entrance at the larger. The reason of this is obvious, the sound being *condensed* in its passage through the tube. On this principle, especially when conjoined with the following, ear-trumpets are formed; the sounds being collected by the large aperture of the tube and thrown in a more condensed form on the ear.

When sound passes through a long tube, it is also stronger at its exit, than it was at its entrance. For as light reflected by mirrors is brighter and hotter, so sound reflected by elastic bodies, is made stronger, or louder than before. The sound

in passing through the tube is continually reflected by the sides thereof, and of course condensed and strengthened in the axis. Hence speaking-trumpets, horns, &c. increase the loudness of sound.

When sounds are weak, the tympanum has the faculty of becoming more tight, so as to receive a stronger impression from them. On the contrary, when the sounds are strong, the tympanum relaxes, so that the impression which they make on it may be less violent. This is analogous to the contraction and dilatation of the pupil of the eye in like circumstances.

Distance is judged partly by the faintness and indistinctness of the sound, and partly by other means not yet wholly discovered.

## C H A P T E R     III.

O F

## H Y D R O S T A T I C S.

**I**F a body be let fall in *vacuo*, it will descend towards the earth with the greatest velocity or swiftness that the power of gravity is capable of giving it. A feather let fall in an exhausted receiver descends to the bottom as fast as a shilling.

But if the feather be let fall in a fluid, its descent will be hindered, and that more according as the fluid is denser; so that if the fluid is of equal density with the feather, the latter will not descend; and if the feather be rarer than the fluid, it will, on the contrary, levitate, or rise to the top. See likewise what was said of specific gravity in the introduction.

A feather and a shilling, in *vacuo*, descend with equal velocity. In air the feather hardly descends at all, because of its rarity; whereas the shilling, being much denser, is very little interrupted by the air in its descent. But in quicksilver, the shilling rises to the top as well as the feather, though with less velocity.

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Now

Now the fundamental law in hydrostatics depends on the force with which any body descends in a fluid. In *vacuo* this force is greatest of all; in air 'tis less; in water still less, and in quicksilver, or other denser fluids, still less than in water. The force of descent is called the *weight* of the body in the given fluid. And hence we say that any body, suppose gold, weighs lighter in air than in *vacuo*; lighter in water than in air, and lighter in quicksilver than in water.

If I would know the comparative weight of ivory in water and in air, I fasten the ivory by a slender thread to one of the scales of a balance, so as that it may hang down below the scale; I weigh it in air, and find that it weighs 60 grains. I now let the suspended ivory down into water in a basin, the scales themselves remaining in the air, and find that the ivory weighs lighter in the water than it did in the air, the scale with the weights in it descending. I therefore add weights to the scale to which the ivory is suspended, till the equilibrium is restored, and find that 31 grains are necessary for that purpose; 31 subtracted from 60, leaves 29; so that a piece of ivory, which in air weighs 60 grains, weighs, in water, only 29.

Solid bodies are weighed in fluids for the purpose of discovering their specific gravities. I would know, for example, the proportion that  
the

the specific gravity of ivory bears to that of lead. I take a piece of each of them, weighing in air exactly 60 grains each. By weighing them in water I find that the lead loses  $5\frac{3}{4}$  grains, and the ivory 31 grains. Consequently the specific gravity of lead, is to that of ivory as 31 to  $5\frac{3}{4}$ , or in the inverse proportion of their weights. That is, lead is above five times heavier than ivory. In this manner may the specific gravities of solids be ascertained. If the solid to be weighed is liable to be dissolved in water, it may be weighed in some other fluid, in which it will not be dissolved. In oil, spirit of wine, or quicksilver for example.

By this method the comparative specific gravities of solid bodies may be estimated. Those of liquids may be discovered in a manner somewhat similar.

The proportions of the specific gravities of water, and oil of vitriol, for example, are required. I take a piece of lead, which in air, I find to weigh 455 grains. I weigh it in oil of vitriol, and afterwards in water, and the weights are 379, and 414 grains. The loss of weight in the first case is 76, in the latter 41 grains; these numbers are inversely as their specific gravities; and of course the specific gravity of oil of vitriol, is to that of water, as 76 to 41; that is, almost twice as great. It is by these means that the

tables of specific gravities of bodies are constructed, and their densities known.

On this principle likewise, *hydrometers* may be constructed, which are so useful for discovering the purity of vinous spirits, and other liquids. If a piece of metal, glass, &c. be made hollow and thin; it will swim in a liquid specifically lighter than itself; but with this difference, that the lighter the liquid, the deeper will such a vessel sink, or be immersed therein. Spirit of wine is lighter, according as it is more pure, and therefore the deeper such an instrument sinks in it, the greater is its purity. But the hydrometer most frequently used, is a thin, hollow globe of copper (*g*, fig. 25.) with the handle *h*. This globe is so contrived as to be barely sustained in spirit of a certain purity or density, which therefore is called *proof*. If it sinks in a spirit, the specific gravity of the latter is too little, or it is above *proof*. If it requires an addition of weight to make it sink, the specific gravity of the spirit is too great, that is, it is not sufficiently pure. And as heat, by expanding bodies, lessens their specific gravity, there are bits of metal, or the like, to be occasionally screwed on to, or taken from the point *p*, answerable to the degree of heat, and the consequent change of specific gravity of the liquid.

## C H A P T E R IV.

## O F

## E L E C T R I C I T Y.

**E**LECTRICITY is applied to medical purposes, and frequently with good effect. I shall therefore next proceed to give the reader an idea of that entertaining branch of philosophy.

Bodies are divided by writers on this science into *electric*s and *non-electric*s.

The electric*s* are glass, amber, rosin, sulphur, air, silk, and certain other substances;

The non-electric*s* are metals, water, the earth, animal and vegetable fluids, &c.

Electricity is an exceedingly subtle and elastic fluid, which may be rendered sensible, by its effects, to the feeling, and other senses.

Electric*s* are impervious to the electric fluid. Non-electric*s* are readily pervaded by it. For this reason the latter are also called *conductors*, the former *non-conductors* of electricity.

It was shewn in a former chapter, that different bodies have different capacities for containing *fire*; and that at the common temperature some bodies retain a greater proportion of it than others. But that fire has a tendency to diffuse itself over all bodies in such a manner as to preserve an equilibrium with regard to their capacities for containing it; or in other words, till those bodies are restored to an equal degree of sensible heat. When an hotter body is applied to a colder one, the former loses, and the latter gains heat, till the equilibrium between them is restored.

The same rule obtains with regard to electricity. Some bodies naturally retain more of it than others †; but yet there is a like tendency to an equilibrium, as in the case of fire; with this difference, that whereas it is some time before the equilibrium is restored with respect to heat, in electricity it is effected in an instant.

The equilibrium is destroyed by several methods; but that usually employed is *friction*.

If glass, which is an electric, be rubbed with leather, a non-electric, the part of the surface of the

† This holds good not only with different bodies, but even with the same body in different states, as was shewn with regard to fire. Thus glass is an electric in the ordinary temperature of the atmosphere, but if made hot it becomes a conductor. Water is a conductor; but if frozen with a due degree of cold it becomes an electric; and this is also the case with water in its elastic state.

the former which is affected by the friction, will become disposed to attract † or receive the electrical fluid. It will therefore flow from the leather to the glass; and of course from the non-electrics around to the leather, in order to restore the equilibrium.

This increased attraction, or disposition of the glass to receive electricity however, is but momentary; for as soon as the friction is over, it diminishes; and the glass gives out, by degrees, the whole of the fluid which it had absorbed.

If feathers, or other light, non-electric substances be applied to the glass in this state, they violently attract its redundant electricity, and therefore the glass itself which contains it. But as the glass is heavy, and the feather light, instead of the former moving towards the latter, the feather, as being most easily moved, will rush upon the glass.

But when the feather has taken so much electricity from the glass, as that an equilibrium obtains between them, they mutually repel each other, and the latter, being the lightest, is driven away: nor will it be attracted again till it has touched some other substance, to which it

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† The term *attraction*, though strictly speaking, it may be improper, yet having been commonly used as being most convenient for the comprehending of the phenomena of electricity, is here retained.

may impart its acquired electricity. Having done this, it is again attracted by the glass, and afterwards repelled, for the reasons just given: and this happens till the feather and glass have only their natural quantities of electricity, when the attraction and repulsion cease.

To collect this fluid for the purpose of experiments, philosophers have contrived the following apparatus.

A glass globe  $G$ , (fig. 26.) is mounted, and furnished with a rubber  $R$ , as in an electrical machine. The rubber is a piece of leather, stuffed, and fastened on a brass handle, with a spring, so as to press against the globe. A gun-barrel, or other non-electric body is *insulated*, (that is, suspended by silken strings, or otherwise, so as to have no communication with any non-electric;) one end of it armed with points, being at a small distance from the globe. This is called the prime conductor ( $C$ ). It may be observed, that the rubber should also be insulated, or fixed upon baked wood, glass, or the like, so as not to be in contact with any other non-electric.

If the globe be whirled round by means of the wheel  $W$  and the string  $S S$ , a friction will take place between it and the rubber, and it will become disposed to receive electricity; as mentioned before. It will therefore begin to draw the electric fluid out of the rubber; but as the parts

parts of the surface successively rubbed, will also presently begin to let it go again, it will be attracted by the conductor *C*, and accumulated thereon. But when the fluid is all attracted from the rubber, the accumulation on the conductor can be no farther increased, and the process is at a stand.

If however, the rubber be made to communicate with the floor, the earth, or any other non-electric, (as might easily be done, by means of a metal chain, or other conducting substance,) the electricity contained in these bodies will flow to the rubber to restore the equilibrium. The globe may again be excited by friction against the rubber. The operation may be continued at pleasure, and the fluid may be accumulated on the conductor in still greater quantity.

It may at first view be imagined that the faster the globe is whirled, the more electricity will be thrown on the conductor. But this will not happen when the velocity of the rotation exceeds a certain degree, because the disposition given to the parts rubbed, of absorbing electricity, does not go off before these parts successively arrive at the conductor; and to the effect in question, it is necessary that they should on the contrary have begun to give out their acquired electricity by that time,

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As there is a violent tendency in the electric fluid to disperse itself in equilibrio in all bodies, according to their dispositions for retaining it, any non-electric applied to the conductor, having a less relative quantity of that fluid, will take from it so much of its electricity as to restore an equilibrium between them; or the fluid will rush with great violence from the conductor into the body, in order to restore that equilibrium.

The human body is a non-electric, and of course this will also be the case with it. If the finger, or any other part, be applied to the conductor, the fluid rushes with great violence into that part, and hence the uneasy sensation, or painful shock which is felt on those occasions.

If the person stands on a non-electric, the fluid will pass thro' the body into the floor, &c.

But if he stands on an electric, (suppose resin, or glass,) the fluid which he received from the conductor will remain in his body, being hindered from passing off by that electric, and by the air on every side around him, which is also an electric; and therefore he will be electrified as well as the prime conductor; and indeed a human body thus insulated, or placed on electric substances, might serve for a prime conductor, and

and receive an accumulated quantity of electricity.

If any person not electrified, or any non-electric, be applied to the person thus electrified, or, which is the same thing, if he steps on the floor, or touches any other non-electric not insulated, the fluid will rush from him into that other body, the same as it would from the conductor; and he will feel the same sensation at parting with the fluid as he did in receiving it from the conductor. 'Tis remarkable that a visible spark, and a snapping noise happen on these occasions, together with a sulphureous, or phosphoreal smell.

If the electrified person touches another who is insulated, or placed on electrics, the fluid will not pass off entirely, as happens where the person, or other non-electric touched is not electrified, but only half of the accumulated fluid will pass from the former into the latter, or so as to preserve an equilibrium of the fluid between them. Both these persons therefore will be electrified, but only half as much as the first was before such communication.

When a person is electrified, the fluid may be drawn off from him at any part by applying a non-electric substance to that part. Thus, if the finger, knuckle, a key, or the like, be applied to the eye, the fluid will be discharged through

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that organ. If it be applied to the ear, the fluid will be discharged into it through the ear, and so of any other part. Hence in medical electricity, we can draw off the fluid through any part that happens to be affected, and thereby are frequently enabled to do service, or even effect a cure. The fluid may also be received into an insulated body at any particular part. It may likewise be made to enter the body at any part, and pass through, or out of it at any other part, by letting the prime conductor, and the non-electric properly communicate with those parts. Thus, if a finger touch the prime conductor, and the toe the floor, the fluid will enter the body at the finger, and pass out of it at the toe.

When the human body, or other conductor contains more of the electric fluid than it naturally would, it is said to be electrified *positively*, or *plus*. But if it be made to contain less of that fluid than its natural quantity, it is said to be electrified *negatively*, or *minus*.

It was shewn, for example, that when the rubber is insulated, or has no communication with other non-electrics, the excited globe presently draws away all the electricity which that rubber naturally contains, and which is again attracted from it by the prime conductor. The conductor therefore is electrified *positively*, or has *more* of the fluid than its natural quantity, the rubber on the

the contrary is electrified *negatively*, or has *less* of the electric fluid than it would naturally contain. From whence it will easily be perceived, that whereas the conductor will *part with* electricity to any non-electric applied to it, the rubber will, on the contrary *attract* electricity from such non-electric; these opposite affections of those bodies being equally the effects of the tendency of the fluid to restore the equilibrium.

Thus, suppose three bodies, hot, lukewarm, and cold. The lukewarm body applied to the cold one, will communicate fire to it, till both become of an equal heat. But if the lukewarm be applied to the hot one, the latter will communicate fire to the former; and when the equilibrium is restored between them, they will both be hotter than naturally, as in the other case they were colder.

In like manner, if the human body, or other non-electric, *insulated*, touch the prime conductor, part of the fluid will rush from the conductor into the body, and they will both be electrified positively, though in a less degree than the conductor was before. But if the body touch the rubber, the electricity which the body naturally contains, will on the contrary, rush from the body to the rubber, till an equilibrium obtains, and then both will be electrified negatively, tho' in

in a less degree than the rubber was previous to such communication.

If now the machine be worked, the globe will again attract electricity from the rubber, and the rubber from the insulated human body in contact with it; the fluid will be accumulated upon the conductor; and this process may be continued till all the electricity which the body naturally contains, be drawn out of it, when the process will be interrupted, or cease, as before. The body therefore will now be electrified *minus*, in the greatest possible degree, and will therefore attract the electric fluid with the greatest violence from any non-electrics which contain it; and thus may we electrify with the body in a negative state as well as when in a positive one; for whether the body receive or part with this fluid, the sensation and other effects are the same, so it be done in an equal degree. It may likewise be remarked, that if the body be in a negative state, yet if a body still more negative be applied to it, it will part with electricity to that body; on the contrary, if it be in a positive state, yet if a body still more positive be applied to it, it will receive electricity from that body; and the sensation, and other effects will be the same as if the differences, which are here only relative, had been absolute.

Hitherto I have discoursed only of simple electrification. I shall now proceed to the electric

tric shock, or the famous phenomenon of the Leyden phial.

Let a pane of glass be coated, or covered with tin-foil, or other proper non-electric matter, so as to leave a sufficient margin all round, See figure 27. and let one side of this coated pane be made to communicate with the insulated rubber by means of a non-electric, suppose a wire. If now the machine be worked, the globe will attract the electricity from the rubber, and the rubber from that side of the coated glass, till it has taken all the electricity out of that side. If a proper communication had also been made between the conductor and the other side of the glass, all the electricity that was in the first side would be communicated to the second, so that the first side will be electrified negatively, being deprived of its natural quantity of the electrical fluid, the second side positively, containing twice its natural share. The glass in this state is said to be *charged*.

Now from what has been said it will easily be understood that the negative side has a violent attraction for its natural quantity of electricity, and that the positive side has as violent a tendency to part with it to bodies which have less. But as glass is an electric substance, and therefore impervious to electricity, the fluid cannot

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pass through it to restore the equilibrium, neither can it pass over the edges of the glass from the positive side, on account of the margin, for the same reason. But if a communication be made from one side to the other, by means of non-electrics, or conductors of electricity, the fluid from the positive side will instantly rush with great violence through such conductors to the opposite side to restore the equilibrium; and if the human body be used for that purpose, the fluid will in course pass through *it* to the negative side of the glass. And as in its passage it gives a very smart, sudden, and painful sensation to the body, this is called the *electric shock*.

A pane of glass however is not absolutely necessary for this purpose. Any glass vessel may be made use of with equal effect, and a large phial, or else a glass jar, is usually employed.

When the shock is required to be strong, several or many such jars are connected together by means of wires, from their insides and outsides, terminating in two rods; and the discharge is made by forming a communication between them, either by means of the human body, or other non-electrics, and the shock is greater according as more jars are employed; insomuch that not only small animals, but even human beings

may be killed by the shock from a sufficient number of such jars.

When several or many jars are employed in this manner, it is called an *electrical battery*, and the discharge is called an *explosion*, the report being as loud as that of some pistols.

There are other methods of exciting electricity besides friction, as, by heat and cold, &c. but which do it on a similar principle with that, viz. either by increasing or diminishing the attraction of the body for electricity. But of late years philosophers have discovered a most extraordinary mode of acquiring this fluid, for the discovery of which we are indebted to the illustrious Dr. Franklin; and this is *the drawing it down from the clouds*. For that great man has found that the electrical fluid and lightning are one and the same matter. That the clouds usually contain a considerable quantity of it, that it might be obtained from them by means of a kite, or even by a pointed metallic rod, reaching but a little way up into the air; and that this rod, by communicating with an electrical apparatus, will, when the air abounds with electricity, furnish it as well, and often in greater quantity, than can be ordinarily collected by means of a globe. The same philosopher has further proved, that a flash of lightning is only a greater electrical spark,

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and thunder a louder electrical snap or explosion than what are ordinarily produced by our electrical experiments.

Dr. Franklin has farther shewn, that as metals are the most perfect conductors, or attract the electrical fluid more than other non-electric substances, buildings, ships, &c. may be secured from damage by lightning, by means of slender pointed rods made of those substances, reaching a little way above the highest part of the building and terminating in the earth, or in water. For a flash of lightning falling on the building or ship, will all be attracted by the rod, and safely conducted into the earth. By the same simple method we may also secure ourselves from damage by lightning, though ever so strong or violent.

If the reader is desirous of further acquaintance with this very entertaining branch of science, he is referred to Dr. Priestley's celebrated history of electricity; or to Mr. Cavallo's and Lord Mahon's performances; in which works he will find all that is yet known on the subject.

Electricity has long been applied to medical purposes, and often with good effect. The disorders relievable by it are chiefly those supposed to arise from obstructions in the nerves; as palsies, gutta serena, epilepsies, and the like. Rheumatisms,

matisms, and other similar complaints have also been cured by it.

The method of application in topical cases, is either by first electrifying the patient, and then drawing off sparks from the part; or else by discharging the electrical shock through it. It is most prudent to try the former method first. If that fails, the latter may be had recourse to; and in obstinate cases the strength and frequency of the shocks may be discretionally increased.

The electric fluid has the effect of a *stimulus* on the body; for when a person is strongly electrified, the momentum of the blood, and perspiration are increased. From a knowledge of this property of electricity, we may frequently be enabled to judge à priori, in what cases it is likely to be of use.

Violent shocks should be administered with caution; but there can seldom any injury arise from gentle, continued electrification; and much good may be expected from a prudent use of it\*.

\* See Mr. Cavallo's treatise on medical electricity, and Dr. Priestley's history.

## P A R T III.

## PHYSIOLOGY.

## INTRODUCTION.

**A**N human body may be defined to be "a machine composed of bones and muscles, with their proper appendages, for the purpose of motion at the instance of its intelligent principle; from this principle nerves, or instruments of sensation, are likewise detached to the various parts of the body, for such information as may be necessary for determining it to those motions of the body which may be most conducive to the happiness of the former, and preservation of both."

The reader may object, that the body consists of other parts besides bones, muscles, and nerves; and may wonder that they were omitted in the definition: But all the other parts, as well as functions of the body, seem to be only subservient to the purposes which the definition expresses: For,

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1. The muscles which are necessary to the motions of the body are from the nature of their constitution subject to continual waste, which therefore is to be repaired by means of some of these.
2. Most of the other parts and functions of the body are either necessary to the action of the muscles, or to the operation of the intelligent principle, or both; and
3. From the sensibility, and delicate structure of the parts, they require to be defended from external injuries.

To illustrate this it may be observed,

1. That the stomach and digestive faculties assimilate the food which is taken to repair the continual waste; and the circulation, besides being absolutely necessary to the action of the muscles, as will appear, distributes this nourishment to the several parts of the body. The glands separate liquors from the blood for these useful subservient purposes. Thus, the liver, the pancreas, and other glands, separate juices necessary to the proper digestion and assimilation of the food. The kidneys strain off the useless and superfluous water, salts, &c. which otherwise, by remaining in the body, would be injurious to it. The brain is supposed to separate a

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fluid for the purposes of sense and motion. And so of other parts.

2. The nerves are not only the instruments of sensation; but 'tis immediately by their means that the muscles are moved. To the motion of the voluntary muscles, the motion of the blood, and of course the vital motions of the system also are necessary; for as the muscles cannot be moved but by means of the nerves, so neither can they if the blood does not flow through them. A certain degree of heat is necessary to keep the blood fluid, and also to the action of the nerves, without either of which, motion could not be performed. Breathing is so necessary to life, that it cannot exist even a few minutes without the exercise of that function; and yet the use of respiration, whereby it becomes so necessary to life, seems to be to keep the body in a proper state for the purposes of muscular motion, &c.

3. The skin, like a sheath, serves to defend the body from injuries. The skull serves for the same purpose to the brain, and the ribs to the heart. The membranes separate the muscles, fibres, &c. from each other; and something similar may be observed of the other parts of the body.

The parts of generation may indeed at first view be considered as an objection; but when we reflect that pleasure is the only end which is had in view by fruition, the objection will be found of no moment.

C H A P-

## CHAPTER I.

## OF THE BONES AND MUSCLES.

THE bones serve to give firmness and shape to the body.

Some of them serve likewise for defence. Thus, the skull defends the brain, and the ribs the heart, as before observed.

But they have also a more important use; for it is by the muscles moving the bones, that the various motions of the limbs, and other parts of the body are performed.

The whole system of bones (called a *skeleton*,) is constructed of many parts, of different shapes, and sizes; joining with one another in various manners, and so knit together, as best to answer to the motions which the occasions of the animal might require.

The muscles move those bones at the command of the will, or otherwise, by contracting their lengths. Imagine two bones knit together, so as to be moveable, and that two equal muscles are affixed to them, one on each side.

These muscles may be either shortened, or lengthened; or, to speak in the language of anatomists, *contracted*, or *relaxed*. If the will acts on the right hand muscle, it will contract and bend the bones to the right. If the will acts on the left hand muscle, it will contract, and thereby bend the bones to the left. But when neither muscle is more contracted than the other, the bones remain strait.

Muscles in general, at least those which serve for voluntary motion, are balanced by antagonists, as in the instance just described. By this means they are kept beyond their natural stretch. When one is contracted by the will, the other relaxes, in order to give it play, or at least is more easily overpowered by the contraction of its antagonist. Also when one of such muscles happens to be paralytic, or destroyed, the other, being no longer balanced or kept on the stretch, immediately contracts into its natural length, and remains in that situation. The part to which it is fixed will in course be affected accordingly. If one of the muscles which move the mouth sideways be destroyed, the other immediately relaxing, draws the mouth awry, and in that situation it remains. The like may be observed of the leg, the arm, and other parts. Some muscles assist one another in their action; and others have different actions, according to their shapes,

shapes, the course of their fibres, and the structure of the parts which they move.

According to the shape and nature of the bones to be moved, and of the motions to be performed, the muscles are either long, or short, slender, or bulky; strait, or round, &c. Where a great motion is required, as of the leg, or arm, the muscles are long; where a small motion is required, the muscles are short, for a strong motion they are thick, and for a weak one slender. For a direct motion, the muscles are strait; for an orbicular motion, circular, as in the sphincters of the anus, and bladder.

Also some of these muscles are fastened to, and move bones, others cartilages; and others again other muscles, according as may best suit the intention to be answered.

Some of the muscles terminate at both extremities in tendons, others only at one end, and others again at neither, for a similar reason.

Each muscle is furnished with a nerve, an artery, and a vein; all of which are necessary to its action, as has been proved by a variety of experiments.

As a particular description of the parts does not come either within the limits, or the plan of this work,

work, the reader, not yet acquainted with these matters, is referred to anatomical authors who treat professedly on them\*.

## CHAPTER II.

### OF THE MOVING FIBRES.

THE fibres may be considered as the component parts of the solids; and they are denominated according to the parts which they compose. Thus the fibres which compose the muscles are called muscular fibres. Those which compose the membranes, membranous fibres; and so of others. But the former are the only ones which we shall have occasion to consider in this discourse, and they may be called *moving fibres*.

When a fibre is drawn out into a greater length than naturally, it has an endeavour to contract.

On the contrary, the nerves have a power of contracting those fibres, or making them become shorter than naturally; but when the influence of the nerve ceases, the fibres become capable of returning to their usual length.

Whatever irritates the fibres occasions this influence of the nerves on them.

\* See Dr. Simmon's Elements of Anatomy, &c.

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Some fibres while in the living body are more irritable than others, or they contract more forcibly with the same degree of stimulus. The fibres which compose the heart are more irritable than those which compose the muscles moving the limbs ; this was requisite, because a greater and more constant motion is required in the heart than in the muscles last mentioned.

Some of those fibres are also more sensible, or endowed with a greater degree of feeling, than others. But the feeling is not always proportionable to the degree of irritability. The heart, though more irritable than the muscles of the limbs, is less sensible. This also was necessary, for if the heart was very sensible, its labour in circulating the blood would be so painful as to be intolerable ; whereas now it is never felt, unless on particular occasions.

The fibres have also an *elasticity*, which is different from the *irritability* described ; and remains after the latter is destroyed. The elasticity is of use to their action. When they are distended, the elasticity helps to contract them ; and contrariwise.

The red colour of muscular fibres depends on the blood. If that be washed out, the fibres are then white.

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If fibres are too much distended, their contractile powers are either destroyed or weakened; and if they are only impaired, some time is required to restore them to their proper state; and in some cases even this is impracticable, the mischief continuing for life. This is the cause of some of those melancholy disorders which are improperly called *nervous*; and of others.

As on the action of the fibres the *functions*, so on the state of the fibres the *constitution*, of the body seems to depend. If the fibres are strong, the individual is strong; if weak, he is feeble. If the fibres are very irritable, he is passionate; if the contrary, inactive and dull. In health the fibres are stronger than after illness. Their state depends also very much on that of the atmosphere. If the atmosphere is heavy, cold, and dry, the fibres are elastic and strong. If light, hot, and moist, the contrary. Moderate cold strengthens or braces up these fibres; but excess of heat weakens them. Hence heat makes us feeble and faint; cold the reverse. From knowing the state of the fibres we are directed to apply the suitable remedies. If they are relaxed, bracing and stimulating remedies are indicated; but if too tense, those of a contrary nature.

## CHAPTER III.

## OF THE BRAIN AND NERVES.

THE brain is the seat of the intelligent principle. From that principle nerves serving for sensation are sent off to every part of the body, to receive the necessary information of the state of the body itself, and of things without.

Another set of nerves are detached to the muscles, or those parts which are to serve for the motions of the body at the instance of the will. Those two sets of nerves seem to be different, because sensation may be lost in a part, yet motion remain.

A third set of nerves serve for the merely involuntary or vital motions of the system, and do not appear to have any connection with the intelligent principle. They perform their offices continually, in sleeping, as well as waking; but the others in waking only.

By these the fibres and parts seem to be recruited, or nourished, in conjunction with the blood; for nutrition is chiefly performed in sleep, when the other nerves are inactive; and it is well known, that

that if the nerve be destroyed, the part which it serves wastes, notwithstanding that the blood and lymph flow through it as usual.

The heat of the body seems also to depend either wholly, or chiefly, on this set of nerves; for it is nearly as great in sleep as in waking, though then these nerves only act; and yet if a nerve be destroyed, the part which it serves becomes cold, notwithstanding that the blood continues to circulate through it †.

That the heat of the blood does not depend on the nerves which serve for sensation is plain, because heat continues in sleep, when they are inactive; also a part which has lost its feeling, but retains its motion, does not always lose its heat.

As the nerves serve for motion and sensation, any obstruction, or compression of them, will occasion palsy of the part or parts which they serve; that is, it will occasion either loss of sense, or motion, or both, according to the nature of the injury. Thus, the optic nerve being compressed, blindness ensues; and the nerves of the leg, loss of motion of that part. By destroying the nerve, nutrition and animal heat will also be injured, as hath already been observed. But the disorders commonly called *nervous*, seem to

† See Dr. Caverhill's Experiments on animal heat.

proceed

proceed for the most part from injuries of the moving fibres, as mentioned in the last chapter.

## CHAPTER IV.

## OF THE CIRCULATION OF THE BLOOD.

THE circulation of the blood was unknown till about 150 years ago, when it was discovered by a countryman of our own, the celebrated Dr. Harvey. For this great discovery, statues are justly erected, and orations yearly pronounced in his honour.

With respect to the circulation of the blood, the body must be considered as distinguished into two portions, *the lungs*, and *the other parts*.

The heart is the power, or mechanical cause by which the blood is circulated. From the right ventricle of the heart there issues a large artery, called the *pulmonary artery*; which goes to the lungs, and is there divided and subdivided into a vast number of branches, too small to be visible. The ultimate ramifications of these branches may be considered as uniting again into larger branches; these again into branches still larger, and so on continually, till at last they form

form only one large pipe, called the pulmonary vein, which is inserted into the left auricle of the heart.

From the left ventricle there issues another large artery called the aorta, which in its passage sends off branches to the arms, legs, head, and every other part of the body. These branches, in the course of their progress, are divided and subdivided into innumerable invisible branches, as was mentioned of the pulmonary artery; and their last ramifications may also be considered as reuniting into branches continually larger and larger, till at length they form only one great pipe, called the vena cava, which is inserted in the right auricle of the heart.

Now the blood is driven out of the right ventricle of the heart into the pulmonary artery, and to all the branches of that artery which are dispersed through every part of the lungs. From these it passes into the branches of the veins; and from all these branches at length into the pulmonary vein itself, which empties it into the left auricle of the heart. This may be called the first stage of its circulation.

From the left auricle it passes into the left ventricle; from thence it is driven into the aorta, or great artery, and into all its branches in every part of the body. From the ramifications of these

these arteries it passes into those of the veins; from these into larger branches, and so on by degrees till at length it arrives at the vena cava, which empties it into the right auricle of the heart. This is the second stage of its circulation.

But from the right auricle it passes again into the right ventricle, from thence, as before, successively to the pulmonary artery, the pulmonary vein, the left auricle, the left ventricle, the aorta, and vena cava, and so on in a perpetual round, which therefore is called *the circulation of the blood*.

The blood however does not flow out of the heart into the arteries continually, but by pulses or fits; when the ventricles are filled with blood from the auricles, the blood stimulates them; and thereby occasions them to *contract*; by such contraction they force the blood which they contain into the arteries. This contraction is called the *systole* of the heart. As soon as they have finished their contraction they relax, and are again filled with blood from the auricles, and this state of the heart is called its *diasstole*. The systole and diasstole of the heart therefore continue on alternately, and hence the *pulsation* or *beating* of the heart.

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The arteries must of course have the like pulsation; the blood being driven into them only by starts, and accordingly we find it in the artery of the wrist, called the *pulse*; the like may also be observed in those of the temples, and other parts of the body. But we may likewise observe that the veins do not beat; the blood flowing on through them in an uninterrupted course; its pulse, by the time that it has passed through such an infinite number of small branches, into larger ones, being entirely broken, and destroyed.

The two ventricles therefore contract and drive out the blood into their respective arteries both at the same time. The two auricles likewise contract and drive their blood into the ventricles at the same time; and hence you will also perceive that the ventricles contract and empty themselves while the auricles are relaxing and receiving blood from their respective veins; and contrariwise; so that their action is alternate.

The heart is a mere muscle, as hath already been observed. The fibres of which it is composed are constructed into auricles and ventricles, for the purpose of receiving and expelling the blood. The coats of the arteries are furnished with muscular fibres, encompassing them circumferentially; consequently when the arteries are dilated by

by the blood driven into them from the heart, they will contract again, and thereby help to drive forward the blood. The veins likewise have this contractile faculty, though in a less degree than the arteries, as having less need of it. And they are besides furnished with valves, which hinder the blood from flowing back into the arteries, though they let it pass on freely to the heart: the latter direction of the blood's motion opening, the former shutting those valves.

From this account of the blood's circulation it will easily be seen that it moves in a direct contrary course in the arteries to what it does in the veins; in the latter it passes *towards*, and in the former *from* the heart. We have an easy proof of this in the common operation of blood-letting. When we have tied up the arm, we do not make the orifice above the ligature, or next to the heart, but below it. If the vein were opened above the ligature it would not bleed. For it only swells next to the hand; which shews that the blood does not flow into the vein from the heart, but from the hand.

It may also have been observed that if the ligature be too tight, the blood will not flow. The reason of this is, that the *artery* is compressed in this case, as well as the vein. And as the *veins* derive their blood from the *arteries*, it follows, that if the blood's motion be hindered

in the latter, none can flow from them into the former. The ligature therefore must be only so moderately tight as to compress the veins, leaving the arteries, which are situated deeper, free. Hence also it may be perceived that the blood really passes from the arteries into the veins, as was described; and that if an artery is to be opened, the orifice must be made above the ligature, because the blood flows into the artery immediately from the heart, and therefore only swells on that side of the ligature.

It may seem strange that these particulars concerning bleeding had been observed by every phlebotomist, and known to almost every medical practitioner for above 2000 years; and yet that none of them should have had the sagacity to infer that the blood circulates, till it occurred to our own countryman before mentioned. When a thing is known, we wonder how it could possibly have escaped our notice; though before, the utmost exertion of the human faculties seemed unequal to the discovery.

Each ventricle of the heart is concluded to expel at least an ounce of blood at a time, and there are about 4000 pulsations of the heart in an hour. If we suppose the quantity of blood circulating in an human adult to be 16 pounds, the whole mass will circulate many times in the course

course of an hour; especially when the pulse is quickened by a fever.

In the preceding account I said, for perspicuity's sake, that the last branches of the arteries run into those of the veins. But it is now the opinion of anatomists, that the arteries carry the blood to the parts to nourish them, and that the veins absorb, or suck up what is superfluous, and return it back to the heart.

As the blood is circulated by pulses, or starts, these pulsations form the grand index to physicians with regard to the health of the body. If the pulse be full and strong, a plethora and increased action of the fibres are indicated: If weak and feeble, the contrary. If quick, a fever; if slow, the reverse. From a variety of other differences in the pulse, which are described by medical writers, and which are better understood by practice and observation, a number of particulars respecting the state of the fluids and solids may be obtained, from which the proper methods of cure are inferred, and which are of important use in the practice of physic.

## CHAPTER V.

## OF THE LYMPHATICS.

INTO the various cells and cavities of the body a thin transparent liquor is poured by the extremities of the arteries, called by anatomists *lymph*. Its use is to moisten and lubricate the parts, for which purpose, by its soft gelatinous nature, it is well calculated. It seems also to contribute to nutrition. This fluid is absorbed from those cavities by a set of vessels called *lymphatics*.

These vessels are very minute, and pellucid; and absorb the lymph on the same principle as small glass tubes suck up water. If a slender glass tube be placed in water, the surface of the water in the tube will be higher than that of the water without the tube; and this difference will be greater as the tube is of less diameter. This phenomenon depends on the attraction between the water, and the inner surface of the tube.

The case is the same with the lymphatics. But these are also furnished with valves, which suffer the fluid to go forwards, but hinder it from

from returning. The lymph, when absorbed as above, is afterwards urged forward by the muscular coats of these vessels in like manner as hath been shewn with regard to the intestines, and blood vessels.

The lymphatics from all parts of the body direct their course towards the same part with the *laetals* or *chyle vessels*, already spoken of; with which they form one general system of *absorbents*. The lymph is poured, together with the chyle, into the left subclavian vein, where they mix with the blood.

If through weakness, or other cause, the lymphatics do not sufficiently absorb the lymph, drop-sies are the consequence; and the like happens when these vessels are ruptured.

When mercurial ointment is rubbed upon the skin, the mercury is absorbed and conveyed into the system, as appears by the salivation which takes place on those occasions. The absorption is made by the lymphatics. Other substances are also capable of being absorbed by these vessels, when properly applied to the skin.

Both the lymph and chyle pass thro' lymphatic glands in their course to the subclavian vein. But for what reason is not yet known.

## CHAPTER VI.

## OF THE PRIMA VIA, AND ALIMENT.

THE human machine is formed on such principles that it cannot continue alive unless it be occasionally recruited by means of food. The principles on which it is constructed require that a very considerable portion of fluids should be continually passing off by perspiration, through invisible pores, in every part of the surface of the body. This evaporation may be rendered sensible by violent exercise or heat; when it appears in the form of sweat. From the lungs it is ordinarily so copious as to be visible to the eye, especially in cold weather; they who have had the curiosity to weigh themselves, have found that the greatest part of what is ate and drank passes off in this manner.

The use of food is to recruit this continual waste. But part of what we usually eat will not serve for this purpose. What is useful therefore is extracted from it; and the remainder cast out of the body by stool and by urine, as will be shewn.

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If the animal fabric could have been formed in such a manner as that the same fluids would have served always, as there would then have been no waste, so there would have been no occasion for supply; and food would have been unnecessary. But on the contrary, life cannot be preserved if the evaporation above spoken of is not continued.

In this chapter I shall describe the progress of the food from the mouth to the blood, and the changes it undergoes in that passage.

From the back part of the mouth passes a tube, called the æsophagus, or gullet, into the stomach. From the right side of the stomach issues another tube, called the pylorus, continued into the duodenum. Into this tube enters the bile duct from the liver, and gall bladder, and with, or near it, another tube called the pancreatic duct, from the pancreas or sweet-bread. The duodenum is continued into the jejunum, which makes the first part of that long flexible tube forming the *winding guts*, and is so called because it is generally empty. The second part is called ileum, and is only a prolongation of the jejunum, and the ileum terminates in that great gut called the colon, the lower part of which, called the rectum, is fixed into the anus or fundament.

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The whole of what has been described is only a production of the same tube, from the esophagus to the anus. It is called, by anatomists, the intestinal canal, or *prima via*, by reason that this is the first passage of the food. It has, by means of its circular muscular fibres, a power or faculty of contracting itself when irritated by distension, and thereby urges forward the food contained in it, as the arteries do the blood. This occasions a visible worm-like motion of the whole guts, when they are exposed to view, and is called their *peristaltic motion*.

From the winding or small guts, and even from the stomach, but chiefly from the ileum, a vast number of very fine slender tubes take their rise. They are invisible unless they happen to be full; and are called *lacteals*, or *chyle vessels*.

The food taken in at the mouth is broken to pieces by the teeth, and impregnated with saliva. From thence it passes into the stomach. It is there mixed with the gastric juice, separated by the small glands of that viscus, by which it is digested, that is, as far as it is capable of being, dissolved. When it gets out of the stomach into the pylorus and duodenum, it is also mixed with bile from the gall bladder, and with pancreatic juice from the sweet-bread; and in consequence of the changes which it undergoes by its mixture with these various liquids, assisted by the warinthe

warmth and gentle triture of the stomach and intestines, it is quite altered in its nature from what it was when first taken\*; so that when it arrives at the small guts, there is absorbed from it, by the chyle vessels above described, a soft and tasteless liquid, called by anatomists *chyle*. If the digestion be perfect, the chyle is the same, whatever be the food it is obtained from. The lacteals which collect this chyle, after properly uniting, empty it into the left subclavian vein, where it mixes with the blood for nourishing the body.

The dregs of the food, from which this liquor was extracted, pass on through the guts, and is cast out as useless.

The chyle therefore may be considered as the pabulum of the blood. It was observed before, that a constant evaporation of fluids from the surface of the body is necessary. The blood supplies this waste. The parts of the body are con-

\* The gastric juice has been shewn, by Mr. John Hunter and others, to be a solvent of the aliment. If flesh, or other food, be digested in this liquid, out of the body, it will in great measure be dissolved by it; and therefore it is now generally held that digestion is performed by *solution*; the gastric liquor being the menstruum for that purpose. The pancreatic juice seems (like the saliva, which it resembles) chiefly designed as a diluent. The use of the bile is not yet properly known. But experiments seem to shew that animal food employs less of it than vegetable. It is therefore probably of great use in animalizing the aliment: and perhaps the blood derives from it its specific power of attracting phlogiston from the body, and parting with it to the air; of which notice will be taken in a future chapter,

tinually

tinually recruited or nourished thereby; and the blood is again recruited for this purpose by the chyle, which, in the course of circulation, is also converted into blood, to serve for the like purposes of nutrition.

As life depends on the recruit of the blood by the chyle made in this process, so health depends much on the goodness of this chyle. If the chyle be perfect, good blood is made; good juices are made from that blood by the glands, and the parts are properly nourished. But if the chyle be bad, it will ultimately affect the body which is to be nourished by it, in proportion. The evil will even be continued in consequence thereof. For the saliva, gastric juice, bile, and succus pancreaticus being vitiated, they will affect the chyle hereafter to be prepared from fresh food. Nature has provided as much as a careful guardian can in these matters. She has furnished the mouth with the faculty of tasting, and the nostrils (which communicate with the mouth) with that of smelling, in order that they may detect any thing improper, and prevent its being taken in to the injury of the animal. If the food endures these tests it is suffered to pass on to the stomach. But that organ has also the faculty of discriminating whether the aliment is proper, and in some cases where the senses of taste and smell are ineffectual. If it be hurtful, or poisonous, it has in many instances

instances the provident faculty of rejecting, or throwing it up. If there are hurtful qualities, which even the stomach cannot discover, the guts often detect them, and have the no less wonderful faculty of hurrying it thro' the body by stool. There are cases however in which none of these tests are sufficient, and bad chyle is after all suffered to pass into the blood. But even there it is thrown off by urine or other secretion, or else a fever is raised in order to expel it by perspiration, which is an effect of the same kind as vomiting in the stomach, and purging in the guts. Abscesses, eruptions, and other means are likewise occasionally employed by nature for the same intention. But there are cases where either the vigilance or power of all these are ineffectual, and in consequence thereof either health is injured, or life destroyed.

## CHAPTER VII.

## OF THE BLOOD.

THE chyle, in the course of its circulation, is converted into blood; as hath already been observed.

They who have dissected bodies with a view to the changes wrought on the fluids in the lungs,  
have

have remarked that chyle is perceptible in the pulmonary artery previous to the passage of the blood through that organ, but not in the pulmonary vein, after such passage. The chyle is mixed with the lymph in the subclavian vein, &c. The more watery part is probably exhaled by the breath; and the remainder incorporated with the mass of blood by agitation in the pulmonary organ.

When blood flows from a vein, it seems to be an homogeneous red fluid. But after resting a while it separates into two substances, a watery part, called *serum*, and a red coagulum, distinguished by the name of *crassamentum*.

The serum, by its sensible qualities, appears to resemble water. It mixes with water into a seemingly uniform aqueous fluid. If, however, this mixture be exposed to a sufficient heat, the serum separates in the form of a white, coagulated substance, which is not redissolvable in the water.

If serum be exposed alone to heat, it also coagulates; and if it be poured into boiling water the same effect takes place. It is coagulated likewise by spirit of wine, æther, and acids. In these and other properties, it bears a very great analogy to the white of an egg.

The *crassamentum* is composed of two distinct substances; 1. the *red*, or colouring part, which may

may be entirely washed out of it by means of water, and, 2. the *coagulable lymph*.

The red part may be distinguished, by means of a microscope, in the form of little globules, floating in the other parts of the blood, like oil shook well up with water. By means of the same instrument, they may be seen moving in the minute blood vessels of frogs, and other animals, from the arteries into the veins; and hence we have an ocular proof of the circulation of the blood.

This substance is of a deeper red in the veins than in the arteries. It acquires its deep colour in the course of its circulation through the body, and loseth it in its passage through the lungs.

The heat of the blood is greater than that of the surrounding atmosphere, its temperature in health, being at about 98 degrees of Fahrenheit's thermometer. In morbid states, it varies from that point; thus, it is hotter in an inflammatory fever, and colder in the cold fit of an ague.

In health, the heat of the blood is nearly the same, whether the surrounding atmosphere be hotter or colder; the vital powers generating more heat in the latter case, and less in the former.

The

The *coagulable lymph*, when separated from the red part, is a white gelatinous substance, and probably the elastic, and glutinous parts of the solids are formed of it.

There is a greater proportion of coagulable lymph in the blood of persons of strong constitutions, than in those of weak ones, and the proportion in the blood of the same person varies according to the strength and other circumstances. The like may be observed of its texture.

While blood remains in the vessels, it continues fluid much longer than it would do in the open air; the action of which disposes it to a speedy coagulation.

When blood has stood for some hours out of the vessels, it begins to putrify; and in putrid diseases this is said to take place, in some degree, even in the blood of living animals.

From the appearance of the blood, many important indications may be drawn. For example, if the crassamentum be of a weak, or lax texture, incrassants are indicated. If tough and viscid, attenuants and diluents. If in over proportion, evacuations; if the contrary, nutritives. The appearance of size, or buff, on the crassamentum, is said to argue too great a fluidity of the coagulable lymph, so that the red globules sink

in it, leaving the upper part of the cake free from them, or in a state of pure coagulable lymph. Hence it is considered as a sign of inflammation. Other indications are drawn from the appearances of blood by practical writers.

## CHAPTER VIII.

### OF NUTRITION.

THE solids, as well as fluids of the body, are in a state of continual waste, and therefore require to be recruited. Hence the necessity of food, as before observed.

The manner in which nutrition is performed is not as yet well understood, but it seems to be performed by the blood, or rather the lymph, in conjunction with the nerves.

If a nerve be divided, the part which it serves, wastes, (especially if it be muscular) notwithstanding that the blood circulates through it as usual. And there are phænomena which shew that the blood is likewise necessary to nutrition.

In the muscular fibres, the basis of nutrition may be the substance of the nerves; but these may require to be assisted by the blood, or its lymph. Other parts may be nourished in diffe-

rent manners, and some of them, either wholly or chiefly by the coagulable matter of the blood. The solids seem for the most part to consist of coagulable matter, combined with water. And the various parts of the body may be enabled, by means of glands, elective attractions, or otherwise, to separate those particles from the blood, and those only, which are most proper for their respective purposes. But this is a subject which requires to be farther investigated by experiments.

## CHAPTER IX.

## OF THE GLANDS.

FROM the blood are separated many fluids; for different purposes, by certain organs called *glands*. Thus,

## THE KIDNEYS

Strain off the urine; which consists of the superfluous water, salts, &c. and which, if retained, would be prejudicial to the animalconomy. Critical discharges of the utmost importance to the body, are also not unfrequently made by the same outlet. This fluid is retained in the bladder, so as to be expelled when convenient. From the appearance of the urine, use-

ful practical indications are frequently formed; as may be seen in medical writings.

#### THE LIVER

Forms the bile or gall, part of which is retained in the gall-bladder, as its reservoir, as the urine is in the *vesica*. The duct of the gall-bladder opens into the duodenum. The pressure of the food, as it passeth through the pylorus, forces the bile into the intestines for the purpose already mentioned.

#### THE PANCREAS, OR SWEET-BREAD,

Forms the pancreatic juice, which is likewise emptied into the intestines for diluting and furthering the digestion of the food.

#### THE SALIVAL GLANDS

Secrete the spittle, for the purpose of moistening, and perhaps assisting the digestion of the food.

#### THE GLANDULES IN THE STOMACH

Secrete the gastric juice, for the purpose of dissolving the food. Those in the intestines separate a liquid which lubricates the guts, for the more easy passage of the aliment, and perhaps also to assist in its assimilation.

#### THE TESTICLES

Form the vivifying principle in males, or the seed, improperly so called, as do

#### THE OVARIES,

The true seed, in females.

## THE BRAIN

Seems to secrete a substance which, being conveyed by the nerves, assists in nutrition. By means either of the same, or some other matter or fluid, sensation and motion are probably performed.

The other glands have likewise their respective useful offices.

The theory of glandular secretion has not as yet been satisfactorily explained.

From irregularities in the glandular secretions many disorders arise. If the bile be obstructed, jaundice is often the consequence. If perspiration; colds, plethora, and fevers succeed. If the gastric juice be deficient in quantity, or vitiated in quality, digestion is injured. And the like may be observed of the other secretions.

Medicines, in some cases, act on the glands. Cathartics increase the secretion by the glands in the intestines; and diuretics operate by increasing the action of the kidneys.

By increasing some of the secretions many disorders may be cured. A dropsey, for example, is removed by diuretics.

When one secretion is immoderate, it may, in some cases, be checked by augmenting another.

A salivation is diminished by a cathartic: and perspiration by an encreased secretion of urine. And there are other uses of the glandular secretions to be met with in practical authors.

## CHAPTER X.

## OF PERSPIRATION.

**A**N animal body is formed on such principles that its solids, particularly the muscular fibres, are in a continual state of waste; and both these and the fluids require to be constantly renewed. Hence follows

1st, A necessity of their being frequently recruited by means of food, as hath been shewn, and

2dly, A like necessity of a continual discharge of the old and effete materials.

Agreeably to this, we find that from every part of the surface of the body, and from the lungs there constantly exhales a considerable quantity of vapour, called by anatomists the matter of perspiration.

This vapor usually transpires in an insensible manner. But if perspiration be encreased by

R 3 exercise,

exercise, or other cause, it appears in the form of small visible drops, and then it is termed sweat. In cold weather the evaporation from the lungs is condensed into a visible steam; it may even be collected in a liquid form by breathing on a glass, or other proper vessel. More than half of what we eat and drink usually passes off in these two ways, as may be seen by the experiments of Sanctorius and others.

The perspiration by the skin is supposed to be either secreted by glands, or exhaled by minute extremities of the arteries of the cutis. It is probable however, that the matter exhaled by the lungs is different from that which passes off by the skin. We already know that phlogiston is discharged by the lungs, but not by the external surface of the body; the skin being a substance of such a nature as to hinder the requisite action of the air on the blood for that purpose. This observation, compared with the following chapter, may enable us to understand, in some measure, the action of air on wounds.

From what has been said, it is obvious, that perspiration cannot be much increased, or diminished, without affecting the health. If it be obstructed, fulness of the vessels is apt to be produced; together with colds, fevers, and the like. If it be too copious, lassitude and weakness follow; also as the blood is thereby deprived of its

its more fluid parts, the remainder will be more viscid, and circulate with less freedom. The solids also will become too dry and rigid. A warm atmosphere encreases perspiration; and a cold one diminishes it. It frequently happens that when perspiration is diminished, the urinary secretion is encreased; and contrariwise. The matter of perspiration is even said to be very similar to that of the urine.

CHAPTER XL

## OF RESPIRATION.

**I**T has been shewn that the blood has a *double circulation*, or that the whole mass passes first through the lungs, and afterwards through the body.

I have, in some measure, explained the uses of the latter circulation; those of the former shall next be discoursed of.

The lungs are contained in the thorax; and are divided into two lobes. The trachea, or windpipe, also divides into two branches, one of which is sent to each lobe, where it is subdivided into a vast number of ramifications, ultimately terminating in little vesicles, which, when distended with air, make up the greatest part of

the bulk of the lungs. The branches of the pulmonary artery and vein accompany those of the windpipe, and are spent upon the coats of those vesicles. The mass of blood is not carried to the lungs for their nourishment, there being other smaller blood vessels destined for that purpose.

The thorax has an alternate motion of systole and diastole, called *respiration*. At the diastole the air is admitted into the lungs, and this is also called *inspiration*. At the systole the air is expelled from the lungs, which systole is likewise denominated *expiration*.

The nature and properties of air have already been explained. Among others it was shewn, that it presses with a great weight on all things about the surface of the earth, and that it is elastic, or capable of expansion and compression, of rarefaction by heat, and condensation by cold.

The muscles which cause expiration having just finished their contraction, they begin now to relax; the blood driven from the heart into the pulmonary arteries stimulates to inspiration. The external air rushes into the lungs, which are thereby inflated. They fill and dilate the thorax, drive the diaphragm downwards, and by the help of muscles, which serve for inspiration, distend those which serve for the contrary motion,

motion. But those muscles, thus distended, resuming their contractions, re-contract the cavity of the thorax, and thereby expel the air from the lungs. The muscles serving for inspiration, now beginning again to act, the thorax is dilated as before, and this continual alternate dilatation and contraction is called *respiration*.

When the lungs are distended, the blood circulates freely through them; but its passage is much more difficult in expiration. Also as the branches of the arteries and veins run in directions parallel to those of the windpipe, the air in inspiration may perhaps help forward the blood in the arteries running in the same direction, and in expiration it may likewise assist the motion of that in the veins. If breathing be stopt but for a short time death ensues; for if no blood passeth from the lungs to the heart, the circulation, on which life depends, must cease.

It had long been observed, though the reason was not known, that the blood in the veins of the body, and in the arteries of the lungs, was of a darker colour than in the arteries of the body and veins of the lungs; and it was also known that it lost this dark colour during its passage through the last mentioned organ. It had likewise been remarked, that when venous blood was exposed to the air, the surface of it acquired the same scarlet colour as that in the arteries

arteries of the body, and veins of the lungs. This change of colour therefore, it was concluded, depended on the action of the air. What kind of action this was, remained unknown till it was discovered by the industry of the celebrated Dr. Priestley, who found that the dark colour of the venous blood depends on *phlogiston*. That this phlogiston is acquired by it during its circulation through the body. That in its passage through the lungs, the air in inspiration attracts this principle from it, for the same reason as it takes it from combustible bodies; and hence the air expired is almost the same phlogisticated air with that which is produced by combustion. By the loss of its phlogiston the blood recovers its florid colour. From these facts Dr. Priestley justly concluded, *that the principal use of respiration is to carry off the phlogiston which the blood acquires during its circulation through the body.* In confirmation of this doctrine it may be observed, that as candles cannot burn, so neither can animals live, in air that is saturated with the phlogistic principle.

## CHAPTER XII.

## OF MUSCULAR MOTION.

IT is known that the nerve, the artery, and the vein, are necessary to the action of a muscle.

The nerve seems to furnish it with its power of irritability, whereby it is enabled to contract in consequence of a stimulus, or the will. Its sensibility also depends on the nerve\*. If the nerve be destroyed, the power of irritability, as well as of sensibility, will be lost.

A regular supply of blood is also equally necessary to muscular action; for a ligature on the artery, or vein, destroys the power of motion in a muscle, as well as a ligature on the nerve.

The use of the blood in this case seems to be partly to derive the irritable principle into the muscular fibres from the nerves, by the stimulus of its heat and motion; and also to fill up and properly distend the muscle itself. The blood has also probably some other use in this business, not yet properly understood.

\* It is found that those parts of the body which in health are neither *irritable* nor *sensible*, are liable to become so by disease.

While

While a muscle is in action, it is shorter, and also thicker than in its natural state. But its thickness is not increased in proportion to its contraction; the bulk of the whole muscle being less during its action than at other times.

The cause of muscular motion in the abstract seems to be, that by the influence of the nerve, the particles of which the fibres are composed have their attractive forces increased, so that they are drawn nearer together; but that as soon as the influence of the nerve ceases, the increase of attraction vanishes, and the particles recede to their previous distance from each other. The *physical* cause is not yet known.

## CHAPTER XIII.

### OF THE EFFECTS OF AIR ON THE SYSTEM.

FROM what has been said of air in the XIth chapter, and in the first part of this work, it appears that it is a fluid of the utmost importance in the animal economy.

By the XIth chapter it appears that air is fitter for respiration, or for supporting animal life, in proportion as it contains less phlogiston; for then it is more capable of absorbing that principle from the blood in the lungs. The blood thus

thus freed from phlogiston will therefore, in the course of its circulation, more powerfully attract it from the body.

On what account the discharging the blood of phlogiston is so necessary to life, has not as yet been clearly shewn. But it is well known that an animal cannot live many minutes in air that is incapable of performing that effect. The fact alone however is sufficient to shew the great use of pure air, especially in putrid fevers, and similar diseases, when the body abounds with the phlogistic principle.

It may be observed however that phlogiston is not the only principle by which air is rendered unfit for respiration; for if acid, or other irritating particles, be contained in it, they will, by irritating the trachea and lungs, also injure breathing. Thus, the vapour of burning sulphur is insupportable, and that not on account of the phlogiston, but of the acid particles irritating the organs of respiration. The complaints of asthmatic people, with respect to the foulness of air, are in great measure the effects of those irritating particles.

Nor is the discharging of phlogiston the only use of respiration. A large quantity of superfluous aqueous matter is carried off by the air in the lungs, as is evident in cold weather, when  
it

it is visible ; and it has not yet been proved that this matter is exactly of the same kind with that which passes off by the skin.

A dry and heavy air is better for breathing than a moist and light one, respiration then being not only performed with greater freedom, but more phlogiston, and also more perspirable matter is conducted off ; and if the air in this state be also warm, it is better for breathing than when very cold, because by cold the moisture is condensed, and falls back upon the lungs ; hence coughs, &c.

The air in the lungs is also made subservient to other purposes besides those described. Speaking, smelling, coughing, sneezing, dejection, and various other actions are performed by means of it.

With regard to the *external* effects of air, the elasticity or strength of the fibres is known to depend very much on the state of the air incumbent on the body.

That the atmosphere presses upon the body with a very great weight, was shewn when treating of air, and from thence also it may be understood that the pressure of the external air is resisted, by the spring of the air within the body. These ought precisely to balance each other.

But

But when the atmosphere is light, the resistance of the internal becomes greater than the pressure of the external air; the vessels then become turgid; the fibres cannot contract so freely and powerfully as they ought; the circulation, secretions, and other functions will go on more heavily than usual; a general lassitude is felt; the voluntary motions are performed with more difficulty and labour; and from what we feel, we falsely imagine that the air is *heavier* than usual.

When the atmosphere is heavy it presses with a greater weight on the body, and overcomes the resistance of the internal air, and of course the contrary happens to what has just been described. The fibres are more elastic; the vessels contract with greater freedom and force; and the circulation, and other vital functions go on brisker than usual. The voluntary motions are performed with greater ease. The body feels more light and alert, and we falsely imagine the air itself to be *lighter*. This state of the air however, is apt to generate an inflamed state of the blood; hence ardent fevers, and other inflammatory disorders frequently arise, as do disorders of a contrary kind when the atmosphere is too light.

A moist air relaxes the fibres, and disposes the fluids to a putrid state, and as in a moist state of the air, the atmosphere is generally light, the lassitude, the weak crisis of the blood, the sluggish

gish circulation, and disorders arising from them will conspire with the ill consequences of the moisture.

The effects of a dry air on the body are the reverse of these ; and as such a state of it seldom happens but when the atmosphere is also heavy, it will be more favourable to the production of inflammatory diseases.

A warm atmosphere relaxes the fibres, and favours a dissolved state of the blood. If this be joined with a light and moist air it will augment the ill effects of these on the body ; but cold will counteract them. A cold air braces up the fibres, and enables the vessels to contract with greater power. If this be joined with a dry, heavy atmosphere, it increases the evils of which these latter may be productive ; but the ill consequences of a moist and light atmosphere are counteracted by it \*.

By these considerations we may be enabled to form proper indications in regard to the treatment of diseases in the different states of the air ; and also with respect to food, or other proper management in health, for preventing or guarding against the ill effects of these respective unfavourable states of that element. For example, when the air is very moist, light, and warm, a

\* Perspiration is also increased by a warm atmosphere, and lessened by a cold one.

regimen of a more bracing and antiseptic kind is requisite than in a contrary state, where a relaxing and antiphlogistic treatment is more proper. But from a knowledge of the disposition of the atmosphere, and the state of the patient, the practitioner's sagacity will better point out the mode of treatment than many volumes. Having a clear conception of the premises, he will see, as it were by intuition, the consequences. And I have made it my business rather to inculcate an idea of the premises alluded to, than to shew the various and almost infinite results and applications of them, which is much better left to the reader's sagacity. He will notice in particular, that the symptoms of diseases will be often varied, according to the different states of the atmosphere; by want of attention to, or knowledge of which, the ignorant practitioner must frequently be misled.

The effects of winds depend on their temperature, as to heat and cold; on their moisture or dryness; and on the lighter or heavier state of the atmosphere which they occasion. And therefore they may be referred to the preceding heads.

It may be observed, that winds will feel cold, though they are no colder than the other parts of the air. The wind from a pair of bellows feels cold to the hand, though the thermometer shows it to be of the same warmth as before it

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was thus put in motion. For the air immediately surrounding the skin is warmed by the heat of the body. But this being forced away by the current of wind, the fresh air must needs feel colder.

Cold contracts the pores, and checks and condenses the perspiration of the part; and hence it is that we are so liable to get cold when a part of the body is exposed to the action of wind.

Winds in general however are healthful, as they drive away the stagnant air, tainted by exhalations from the earth, by animal respiration, &c. and supply us with that which is more pure.

Besides heat, cold, moisture, dryness, and different weight, the air may be affected by exhalations from the earth, by noxious particles brought by winds, and the like; but these, excepting phlogiston, which has already been spoken of, we are as yet so little acquainted with, that we cannot speak with any degree of certainty about them. It is to be hoped that philosophy will in time throw light on this interesting subject, since most of the contagious and pestilential diseases depend in great measure on such particles abounding in the air.

## CHAPTER XIV.

## OF THE PASSIONS.

THE passions influence the body, and some of them in a very eminent degree. They shall therefore be the subject of the present chapter.

The passions by which the body is chiefly affected are grief, joy, hope, fear, love, hatred, and anger; the others, being either akin to some of these, or of less moment, need not be specified.

Joy is a violent and pleasing passion, arising on the attainment of any good, especially if sudden or unexpected. This passion occasions a greater determination of the nervous influence into the body than usual; hence it suddenly, and remarkably quickens the circulation of the blood. A pleasing warmth or glow is thrown upon the heart and breast, which are even convulsed, as it were, with transport; and instances have been known where death has been the consequence, when the passion has been very violent and sudden. In this passion the heart in particular seems remarkably lighter; owing to the greater ability

with which it is enabled to circulate the blood, not only because of the increased influx from the nerves, but by reason that the vessels, the muscles, and other parts, on account of the like increase of nervous influence, perform more than their usual share in that circulation, and of course greatly lessen the labour of the heart. The secretions, and other functions of the body also go on with a proportional encrease of spirit.

HOPE, or the probability of attaining any good, is of the same nature with joy, only calmer, or less violent in its nature. The like may be observed of self-complacency, which Mr. Hume calls PRIDE; of successful LOVE, and of other passions of the pleasing kind.

These passions therefore might be employed by physicians as cordials; which they are of the highest kind; and much better than any that the *materia medica* can produce. For example, if a physician is capable of persuading a sick person that he shall recover, such an *hope* will do more towards the cure, in some cases, than medicinal prescriptions; and it is well known that if a patient takes it into his head that he shall die, this contrary passion to hope will sometimes occasion his death.

Care however must be taken to prevent excess in those passions, at least in the violent ones of joy and love, for not only madness or frenzy

may be occasioned, but by exhausting the spirits, they will often bring on a contrary disposition of the system, and the lassitude will be productive of more ill to the body than the hilarity of the passion did good; and the more, as the good was only temporary, whereas the evil will be more lasting. When therefore these consequences are likely to arise from these passions, they should be carefully moderated by a skilful application of passions of an opposite kind.

GRIEF, or that passion which is occasioned by the loss of, or disappointment in, any *good*, remarkably decreases the determination of the nervous influence to the body, directly contrary to joy. Hence it causeth the heart to beat slower and weaker than usual; and as the vessels and other parts of the body will be equally affected, the heart will also have, notwithstanding its lesser ability, a greater share in circulating the blood than usual. Hence it painfully labours, throbs, and is oppressed as with an heavy weight; and as in joy, by the greater determination of the influx from the nerves, a sense of warmth was caused about the heart, and the system in general, that of coldness or damp will now take place, for the contrary reason. This passion also, when very sudden and violent, has been known to occasion instant death. *Grief*, especially that excess of it which is termed *despair*, is not only of longer continuance than joy,

but productive of much worse effects. Loss of appetite, hysterics, hypochondriaca, and melancholy madness, are often the dreadful consequences thereof. It may be added, that in this passion, the secretions, and other functions of the body, are remarkably lessened; and sometimes so much impeded, that the fluids in a manner stagnate, and the system becomes as it were almost inanimate.

Every means should be used to divert the attention of the mind from the cause, or object of this fatal passion, and the introduction of objects which are likely to inspire a contrary affection, should on all occasions be attempted. But even this passion may be rendered useful, as it may be employed to moderate the dangerous excesses of the contrary ones; as hath already been remarked.

FEAR bears much the same relation to grief as hope does to joy; for as hope is a mixture of joy and grief, in which the former preponderates, so fear is a like mixture, in which grief has the excess, as Mr. Hume has elegantly shewn. Fear, therefore, is only a less perfect grief; and its effects on the body are of a similar nature, but only more moderate. Hatred, envy, jealousy, and the other disagreeable passions, have also somewhat similar effects.

ANGER,

ANGER; or RAGE, though a disagreeable passion, has an effect on the body somewhat like that of joy, I mean with respect to the increased determination of the nervous influence into the fibres; but without the pleasing sensation. What was said of that passion may be applied, with proper allowances, to this and to others of the like kind.

The effects of the passions on the body are to be considered as produced immediately by means of the moving fibres; for it is into these that the nerves impart their influence according as they are affected by the mind. Joy contracts, or braces up the fibres more than usual, hence they act more powerfully or with greater vigour; and grief relaxes, or weakens them, whence the force of their action will be less; the like may be observed of the other passions. For the vital functions of the body go on more or less vigorously according as the fibres act with greater or less power. Excesses of passion however, especially if frequent, will strain, or otherwise impair the fibres, &c. and hence those melancholy consequences which were mentioned when treating of the fibres.

It appears therefore that the passions are capable of being applied to useful purposes in medicine. But skill and address are required; and,

perhaps, it will be advantageous to the practitioner if he likewise makes himself acquainted with their metaphysical theory, as delivered by Mr. Hume, and other authors.

## CHAPTER XV.

### OF THE SENSES.

#### OF VISION.

THE doctrine of vision, so far as relates to the refraction of light, was explained in the chapter on optics. The manner in which vision is caused by the rays of light shall be the subject of this section.

The different colours, like notes of sound, may be considered as so many gradations of tone; for they are caused by vibrations of the rays of light beating on the eye, in like manner as sounds are caused by vibrations or pulses of the air beating on the ear. Red is produced by the slowest vibrations of the rays, and violet by the quickest.

In the chapter on optics it was shewn that colours might be excited in the eye without the assistance

assistance of the rays of light, or merely by irritation, as is the case with the sense of feeling. But these colours are the same with those which are excited by the rays of light. For the white colour is like that which ariseth from a mixture of all the rays; and different tones or notes of colour are sometimes observed to arise, like those caused by the refracted rays. Now as the rays cause colours by means of their vibrations, and as colours may be excited by irritating the eye, like those caused by the rays of light, it seems apparent that those colours are the effects of as many different vibrations liable to be excited in the retina, of the same swiftness with those of the respective rays of light.

In the chapter on sound, it was shewn that a musical string, when put into vibration has the property of putting another string into motion, whose time of vibration is the same with its own; or whose note is in unison with it. The same thing seems to obtain with regard to the rays of light, and the vibrations or colours liable to be excited in the retina. If the red-making rays fall on the eye, they excite the red-making vibrations in that part of the retina whereon they impinge, but do not excite the others because they are not in unison with them. And hence it seems to be that the least refrangible rays cause only a red colour. For the same reason, if the violet-making rays strike on the retina they excite

cite all the violet-making vibrations in the part on which they fall, and those only, and therefore cause only a violet colour, and the like may be observed of the rays which cause other colours. From hence it may be understood that the rays of light do not cause colours in the eye any otherwise than by the mediation of the *vibrations or colours liable to be excited in the retina*; the colours are occasioned by the latter; the rays of light only serve to excite them into action. So likewise if blue and yellow-making rays fall together on the same part of the retina, they excite the blue and yellow-making vibrations respectively, but because they are so close together as not to be distinguished apart, they are perceived as a mixed colour, or green; the same as would be caused by the rays in the midway between the blue and yellow-making ones. And if all sorts of rays fall promiscuously on the eye, they excite all the different sorts of vibration, and as they are not distinguishable separately, the mixed colour perceived is white; and so of other mixtures.

We are therefore perhaps to consider each of these vibrations, or colours in the retina, as connected with a fibril of the optic nerve. That the vibration being excited, the pulses thereof are communicated to the nervous fibril, and by that conveyed to the sensory, or mind, where it occasions, by its action, the respective colour to be

perceived. Also that there are in the retina a great number of vibrations of the same times, or kinds, and that all the different ones are mixed equally together throughout the whole organ.

## OF HEARING.

As colours may be excited by irritating the retina, so there are sounds liable to be excited by pressing or irritating the ear. The tinnitus aurium, or ringing in the ears, had long been noticed by authors. By pressing the ear with the finger, and otherwise irritating it, it has been found that a regular scale of notes, or musical sounds, might be excited; and that the ear seems to contain all manner of them, from the lowest, or most grave, to the highest, or most acute. It is probable therefore, that the vibrations of air cause sounds by the mediation of these, in like manner as the rays of light were supposed to cause colours by means of the vibrations liable to be excited in the retina.

The pulses or vibrations of the air beat upon the tympanum. The internal sounds however, or those liable to be excited by pressing the ear, do not seem to be in the tympanum, but in the labyrinth and cochlea, which are the inner parts of the ear. Behind the tympanum is a cavity filled with air; from its resemblance to that instrument, it is called the *drum*, of which the membrane called *tympanum* is considered as the head.

head. In the tympanum only the sense of feeling can be excited. When a sound enters the ear it beats upon that membrane; and the pulses are propagated thro' the drum into the cochlea and labyrinth. It there probably excites the unison internal vibration, and thence causeth a sound, in the same manner as was shewn with regard to colours. The note of the sound therefore, and also its loudness, seem to be determined by the internal sound excited in the labyrinth; but the situation, and other particulars of it, are probably known by means of the other parts of the ear, in a manner not yet properly understood. See also the chapter on sound.

#### O F F E E L I N G .

Hearing and seeing are confined to very small portions of the animal, the *eyes* and *ears*: but feeling is an universal sense, being distributed throughout the whole body.

Hearing and seeing are capable of being excited by mere irritation, as hath been shewn; and they seem to be both occasioned by vibrations liable to be excited in the organs of those senses, and carried, by the nerves to the sensory, or mind. Feeling is so liable to be excited by this means, that it is ordinarily excited by no other. And therefore it should seem that feeling is also occasioned by vibrations liable to be excited in those parts which are endued with this sense.

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The whole cutis, or skin, is possessed of the sense of feeling, and anatomists shew certain small pyramidal bodies, which they call papillæ, as the immediate organs of this sense; perhaps we may rather say, of that particular modification of it, called *touch*.

When the sense of feeling is excited with an undulating motion, as by means of a feather, or the like, it yields that pleasing kind of sensation called *tickling*.

When feeling is excited very strongly, it degenerates into *pain*, which though disagreeable, is of the most important use, for by it we are informed when any thing is injuring, or destroying the body, and aroused to remove the cause.

Different parts of the body are endued with different degrees of feeling, suitable to their different uses. Thus, the hair, nails, and cuticle have no feeling; the bones very little; the gums, the heart, and some other parts have less than the flesh in general, for else the former would be hurt by hard food, and the labour of the latter in circulating the blood would be continually sensible and troublesome. But the membranes are, in general, the most sensible parts of the body, though these also differ in this respect, according to their several uses.

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The difference between irritability and sensibility was shewn when discoursing on the fibres.

Feeling is by far the most useful, extensive, and important of the senses, and may be said indeed, to be the basis of them all. Vision would be of very little use to us, if it was not aided by the sense of feeling. The picture of an object, for example, is painted on the retina, by the rays of light; yet it is not merely by this picture, but by the eye tracing the boundaries of an object, that we get the idea of its shape, the eye only considering that point of an object which lies in the optic axis, at a time; so that it is properly by means of the sense of feeling, that we get the idea of an object's shape. The like may be observed with regard to the situation, motion, &c. of objects. With respect to hearing, we probably gain an idea of the situation, &c. of sounds, entirely by means of feeling. In short, it is to this sense that we are indebted, either immediately, or indirectly, for by far the greatest part of our knowledge; as the reader will find by consulting the authors who have best treated on those subjects in a metaphysical view.

To feeling may be added the sensations of heat and cold, which are capable of being excited wherever the sense of feeling is found, and therefore seem to be only certain modifications of it. Heat ariseth in a part when a substance hotter than

than that part is applied to it, and cold in the contrary case.

#### OF TASTE, SMELL, HUNGER, THIRST, &c.

Taste, and smell, differ from the senses of seeing, hearing, and feeling, in that they cannot be excited by merely pressing, or irritating the organs, as happens with the others. The like may be observed of hunger, thirst, &c.

From odorous bodies, effluvia, or very subtle particles, are continually flying off. These particles being drawn up the nostrils, with the air in inspiration, act upon the organ of smelling, in the os cribriforme, and, according to their several natures cause different smells.

As the particles exhaled by the odorous body are in greater plenty near the body than at a distance from it, smells are weaker as the body emitting the odour is more remote, and that in a duplicate proportion to their distance, as those who are skilled in mathematics can easily demonstrate.

Also when the air is moist, particles exhale in greater plenty than when it is dry, and in a warm air more than in a cold one, and therefore the smells of bodies are more powerful at those times than at others.

#### TASTE

TASTE is excited by saline, and certain other particles of bodies, which must either be in a liquid form, or capable of being dissolved into a liquid by the moisture of the tongue, for otherwise no tastes are excited by them \*.

The papillæ in the tongue are the organs of taste; and on them the liquids which are capable of exciting this sensation act. As the particles are of different natures, they cause different tastes, and tastes of the same kind are stronger according as the particles more abound in the liquid.

THIRST is an uneasy sensation in the throat, arising from a want of sufficient moisture in that part.

HUNGER is an uneasy sensation in the stomach, arising from want of food. It is occasioned by the juices of that viscus, which not being employed in digesting the food, stimulate the stomach.

#### REMARKS ON THE SENSES.

The senses serve to inform the intelligent principle of what passes in, or without the body, in order that proper measures may be adopted

\* One reason why some saline substances taste more than others, may be, their dissolving more readily and copiously in the moisture of the tongue. (See page 107.)

The above reasoning seems also to hold good with regard to the organ of smell.

for

for the preservation and happiness of the individual.

Thus, VISION gives information concerning things at a distance, which the other senses could take no cognizance of. It also acquaints us with the objects immediately around, in a much quicker, better, and more accurate manner than the other senses could. To this sense objects appear most delightfully painted with a thousand varieties of beautiful colours, all which they are destitute of naturally, and for which they are indebted to the eye which beholds them. Our happiness was evidently consulted by the Great Creator in this particular.

HEARING also informs us of things at a distance, and in many instances where sight either could not at all, or much less advantageously. On this sense likewise the whole system of language depends, whereby we are enabled to hold converse with one another, and from whence we derive such wonderful advantages. As to the eye, bodies are indebted for the beautiful colours under which they appear to us by that sense, so the like may be observed with regard to music and the ear. Mere motions or tremors of the air, are by means of this sense metamorphosed into the most ravishing harmony. Another very capital instance of our happiness having been considered by the Creator. There is scarce a

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greater charm against the evils of life than music, when skilfully applied, and it has even been introduced into medicine, in this view, with success.

SMELLING also gives us notice of certain qualities of distant objects which could not otherwise be known, as was before observed.

These three senses are, naturally, the only ones which inform us of what passes without the body. By these we are timely warned of an evil, or apprized of a good; and set at work to guard against the one, and endeavour to obtain the other. These senses, in conjunction with the others, inform us also of the qualities of bodies, of our food, and a number of other circumstances, not to our purpose to relate, and hence are of infinite service in the arts, as well as in the ordinary occurrences of life.

Objects of TASTE operate only by immediate contact with the tongue, and therefore do not, like those spoken of, inform us of what passes without the body. Its use is to examine, together with smelling, the qualities of the food. This sense, as well as that of smell, also contribute to our happiness, by metamorphosing the actions of mere inanimate particles into agreeable sensations; and hence we are led, by the mere consideration of pleasure, to the most necessary of our actions, that of taking food;

But as our bodies, from the continual waste of fluids, have occasion to be frequently recruited, nature has provided a still more powerful stimulant, or incentive, to the recruiting the body, I mean the sensation of HUNGER. By this sense we are informed when the taking of nourishment is necessary: in health the call of appetite corresponds exactly enough with the wants of the system in this respect. The gastric juice, whose use is to digest the food, being continually secreted, it follows that when there is no aliment in the stomach to employ it, it irritates the stomach itself, giving us the craving sensation of hunger, and thereby stimulating us to eat, in order to get rid of that uneasy intruder. Nor will it be satisfied till a due quantity of food is taken.

THIRST is instituted with a similar design to hunger. When fluids are wanting in the system, the dryness of the throat in consequence thereof produces the molesting sensation of thirst, which excites us to the act of drinking, in order to remove it, so that, as in hunger, our pleasure or ease and the views of nature are at the same time obtained.

Both hunger and thirst however, are liable to be perverted by ill habits, or by disease, from the views originally intended by them. Thus, drunkards and gluttons frequently hunger and thirst when nature has no occasion either for

solid or fluid aliment, and the like sometimes happens from their being vitiated by disease. The contrary of this likewise *also* often takes place, especially with regard to hunger; it neither giving notice when nature requires a supply, nor is the stomach, through weakness, capable of turning the food, if taken, into proper nourishment. It may be observed too, that when a fever takes place, nature herself providently destroys the appetite, in order to prevent an increase of the disorder.

LUST was implanted in the body with a view to stimulate us to the propagation of the species. A turgidness of the seminal vessels produces an uneasy kind of sensation, which provokes us to the act of copulation. And by that act, as happens with regard to hunger and thirst, we at once get rid of the importunity, and answer the design of nature. The PASSIONS might also be considered as so many different senses; for all of them have their organs and origins in the body.

The sensations by which we are provoked by the contents of the bladder and rectum, to empty these viscera, may also be considered as distinct sensations, for these respective purposes. These sensations however, as well as those of hunger and thirst, seem to be only particular modifications of feeling. Perhaps those of taste and smell are also in the same predicament.

## CHAPTER XVI.

## OF SLEEP.

THE difference of the state of the body in sleeping and waking is, that those parts of the body which serve for voluntary motion in waking, as also the organs of sensation, have their faculties suspended in the former state. At that time, none but the vital motions, secretions, and other functions absolutely necessary to the continuance of life, but which are wholly independent on the will, go on. Thus, the eye does not see, nor the ear hear, nor the skin feel at that time, if the sleep be profound, neither do the limbs move, though the will commands; which is frequently the case in dreaming, or *imperfect sleep*. This term I give it, because when the sleep is profound, the faculty of dreaming also becomes dormant, the mind being asleep as well as the body. The mind therefore at these times is not only unconscious of what is going on in, and without, the body, but the whole animal, considered as a loco-motive being, is in a manner inanimate.

This alternation of sleeping and waking is necessary in order to repair the waste of the parts.

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For *nutrition* is chiefly performed in sleep; and the vital strength recruited. Hence the injury which the body derives from the want of it; hence also we may be enabled to understand the medicinal uses of sleep, which in cases of long and obstinate watchfulness, should sometimes be procured even by artificial means, whether the evil be occasioned by disease, pain, uneasiness of mind, or other cause.

As sleep is seldom profound, we are by the alternation of this state, and waking, furnished with an agreeable vicissitude, a variety of scene. For most people, during the former state, dream. We are then, as it were, in a new world. The cares of life are forgot for a while, and we awake to real action with new relish and vigour.

Delirium, and madness, are also a kind of dreaming, the ideas in both cases appearing to us like real external sensations, for which we at the time mistake them. These however are to be considered as *diseases*.

## CHAPTER XVII.

### OF GENERATION.

**H**UMAN beings are propagated by means of seed as well as vegetables; and the egg is the animal seed. In botany we find, that male

and female parts are necessary to the production of plants as well as in animals. The seed itself is in the female part of the flower, or in the female flower, where the male and female flowers are distinct. But the pollen, or vivifying principle from the male part or flower, is absolutely necessary to rendering that seed prolific, and, with which being duly impregnated, the seed becomes capable of producing a new plant. So in the female of the human species the egg, the proper basis of human seed is contained, but never becomes perfect unless quickened by the vivifying principle from the male; when that is done, the egg or seed is disposed to produce a young animal. In oviparous animals the egg, when it arrives at a certain degree of perfection, is excluded from the body, covered with an hard shell to defend it from injuries, and afterwards hatched by heat. But in human beings, and those animals which are termed viviparous, the egg is hatched in the womb.

In the female of the human species a monthly discharge of bloody matter takes place in the absence of pregnancy; but after conception that discharge generally ceases, it being then turned to the nourishment of the foetus. The improper suppression, or profusion of this discharge, often occasions many disorders, especially those of the hysterical kind.

## CHAPTER XVIII.

## OF THE PROGRESS OF LIFE, AND OF DEATH.

FROM the time of impregnation of the ovum by the male, till the birth, the young animal in the egg, is continually growing, or increasing in size. From the time of the birth it also continues to augment in bulk till it arrives at the state which we term adult; and which, in an human being, is usually reckoned about the twentieth year. The increase of growth is greatest at first, and is afterwards less and less rapid, till the age of puberty is attained.

The reason of this increase of size is, that the pressure of the fluids is greater than the resistance of the solids, so that the latter will in course give way, or expand \*. For in youth the solids are soft; but at the age of puberty they become harder; and sufficiently strong to resist any farther dilation by the pressure of the fluids. They afterwards become more and more hard; and at length so dry and rigid, that they are no longer fit for the purposes of the motions of the system; whence those motions, and of course life, which depends on them, cease; and death closes the scene.

\* The fluids are also in greater proportion to the solids in youth than in age.

## CHAPTER XIX.

## RECAPITULATION.

FROM what has been said, the reader will perceive, that when the solids and fluids are in their proper states and proportions, the aliment good, taken in due quantity, and properly digested; and the air in the most perfect state with respect to density, and the other particulars already discoursed of, the circulation, secretions, and other animal functions, will go on to the best possible advantage; the faculties of both mind and body will be in their most perfect conditions, and a general harmony will reign throughout the system; this constitutes *health*.

On the contrary, when any of these are faulty, the harmony is destroyed, and *disorder* takes place in the system; and the disorder is greater, according to the degree of the defect, or as more of these powers concur in producing it.

Disorders therefore owe their origin either to food, the system itself, or to the air: for casualties, or the effects of external violence, are not here considered.

Disorder

Disorder may be introduced by food several ways; by too little a quantity thereof; by too much; by that which is too poor; by too rich food; by an over proportion of solid to fluid; by too great a proportion of liquid; and by improper food, either considered in itself, or varied in all the preceding cases.

The consequences of taking too little food, even of that which is proper, are too obvious to need pointing out. A waste of the body, weakness, and at length a fever, arising from the gastric juices, which should be employed in digesting the food, getting with the little chyle that is made into the system. An increased allowance of food, is usually the best remedy in this case.

Food in too great quantity produces a plethora, or over fulness of the vessels, and also crude or imperfect juices, the stomach taking in more than it can properly digest. Hence what are vulgarly called humours in the blood, and the eruptions in consequence of these; gouty, and other chronic complaints, fevers, a decay of vital strength, from a general weakness of the over-strained fibres; and at length indigestion, and loss of appetite, the stomach, from the frequent overdistention, losing its digestive power. The mere plethora may be relieved by bleeding, evacuations, and restriction to a due quantity  
of

of food. The other complaints by the same means, in conjunction with those usually prescribed for the respective maladies.

A poor, and rich diet produce effects similar to the above; and, if taken in the same proportion, in a more eminent degree.

If the solid food be in too great proportion to liquid, the blood will be apt to be too thick; and therefore will not circulate so freely as it ought, and the secretions, and perspiration will also be impeded. Hence stagnations of the fluids, obstructions, and the disorders arising from them. An excess of liquid food, I mean if too watery, will occasion a contrary state of the blood, and the disorders consequent thereupon.

The disorders arising from improper, or bad food, will be various according to its nature. Thus, putrid salt provision produces the scurvy, plants of various kinds occasion different species of disorders, and some of them almost instant death, whence they are termed poisons; and so of others. Philosophy has not yet arrived at a sufficient knowledge of the theory of aliment, to determine à priori on these matters, though from the improvements and discoveries almost daily making by the inquisitive, there is reason to hope for greater certainty, and that this part of physiology will also in time be reduced to a science.

science. We know that the food that we take must, among other principles, contain a due proportion of phlogiston in a state proper for assimilation. And hence it seems to be, that animal food is in general best for nutrition; and next to that vegetable. There are few animals but what might be made use of as food. The vegetables proper for diet are far less numerous. But a proper mixture of animal and vegetable food is found to be most conducive to health.

The disorders liable to be produced in the system by the different states of the air were spoken of in the XIIIth chapter, and therefore need not be repeated.

Those arising from the system itself are produced, 1. By the passions; of which we treated before. 2. By too violent exertion, or exercise; and, 3. By a sedentary life, and too much sleep.

The effects of over exertion, and continued fatigue on the system are to strain, wear out, and relax the fibres, and occasion too great an hurry and irregularity in the circulation and secretions, and this is also commonly joined with an anxious state of mind. From hence consumptions, fevers, and other similar complaints arise.

On the contrary, want of exercise, and an over indulgence of sleep, especially if accompanied with a tranquil mind and full-diet, is apt to

to produce plethora, crudities, and corpulency, with their consequences. But when a sedentary life is joined with hard study, and abstemious living, the opposite effects are more apt to be produced, study being a real exercise, and injures the vital powers even more than that.

Many disorders may also be called disorders of the body, which originally took their rise from irregularity with respect to food, the state of the air, or other cause. For example, when a general relaxation of the fibres obtains, we are to consider it only as a disorder of the body, without regard to its original cause, especially if that cause no longer operates; and the intention by medicine must be to restore the tone of these fibres by bracing medicines, and a proper regimen. But if the cause of the disorder remains, the first step must be to remove it. Thus, if by cold air, or otherwise, perspiration be obstructed, and a fever occasioned, we are first to remove the external cause, and then by diaphoretic and attenuating remedies, &c. restore perspiration. The like may be observed of many other diseased states of the body.

The science of medicine is not yet arrived at such a state of perfection as to enable us to reason about the manner of operation of medicine in general, any more than we can about the causes and progress of diseases in many cases; so that much

much must be left to accurate observation ; and our conduct must be regulated by the past experience of others, and our own ; hence the great use of practical writings in medicine. Yet our knowledge in this way is very considerable, and in most cases sufficient. Thus, when from a knowledge of the cause of a disease, we know also that any particular evacuation will cure it, we can, in general, with certainty produce that evacuation, even as a mechanic can produce a desired effect by a known adequate cause. If, for example, we would purge, we not only know what medicines will procure that evacuation, but have our choice of a variety of them, which are known to produce different effects in that way, according to the end to be answered. Thus, manna is merely solutive, but jalap powerfully evacuates also the vascular system, and so of others. The like may be observed of emetics, diuretics, sudorifics, and those which encrease other evacuations. So likewise we can lessen one evacuation by encreasing another. If tonics are wanted, we have our choice of a like variety. And the same may be observed of attenuants, and those for other intentions. We even know the *manner* in which some of these remedies act ; Thus, an emetic acts by vellicating the fibres of the muscular coat of the stomach, thereby exciting it into contraction, whereby the contents of that viscus are expelled. A cathartic acts in a

similar

similar manner on the guts, and also, by irritating their small glands, occasions an increase of their secretions; whence the liquid part of the discharge. The operation of other medicines have also been rationally accounted for by medical writers. But yet to know *how*, or *in what manner*, these medicines produce these effects, would be of little other avail than to gratify curiosity; all that we have occasion to know is, that they *will have these effects*; and our knowledge in this respect may be considered as real science. The skill of a physician consists in acquiring a knowledge of the cause and state of a disorder; and that will point out to him the remedies proper to be administered, at least in cases which are relievable by medicine.

We are even more perfect in this branch of the medical art than in that of the knowledge of the diseases themselves, many of which arise from causes that do not fall under the nature of our senses; as from qualities of the fluids, the air, &c. which philosophy has not yet enabled us to ascertain; in these cases, till we are better informed, experience, and attentive observation must be our chiefest guides. But there are a variety of cases in which we are able to acquire a knowledge of the disorder with sufficient certainty. Thus the causes of diseases with respect to plethora, fever, and the like, are discoverable with accuracy by the pulse. A  
relaxed

relaxed state of the fibres by the weakness and lassitude of the body; a diminished perspiration by the usual symptoms of a cold; and if any doubt ariseth with regard to the state of the blood, the opening a vein will usually satisfy us. In many other cases also the like certainty may be obtained. But I meant only to instruct the reader in *philosophy*; whereas I am now trespassing on the bounds of the *practice of physic*; I shall not therefore any longer detain him on that head.

## P O S T S C R I P T.

**S**EVERAL particulars relating to the subjects treated of in this work having occurred to me, and some of them not being so proper to be inserted in the body of an elementary work, I have judged it more proper to place them at the end, by way of notes ; I have done it in this treatise, because I do not know when I may have leisure to trouble the public in print again :

Page 47. Common air is a mixture of phlogisticated and dephlogisticated airs. When phlogiston is added to dephlogisticated air, not sufficient to saturate the whole, each particle of air is not *partly* phlogisticated, but a certain number of particles are compleatly phlogisticated ; the rest remaining pure air : similar to what happens when a little acid is added to much alkali, the mixture being then neutral salt and pure alkali ; or as when a little iron is added to a large quantity of solution of copper.

Page 56. If the *marine acid* be dephlogisticated, it cannot be made to assume the form of air. The dephlogisticated marine acid dissolves gold ; and aqua regia dissolves that metal only because the marine acid in it is dephlogisticated by the nitrous acid.

Page 72. Professor Bergman has found that spirit of wine contains the *saccharine acid*, with *fixed air*.

Page 83 and 84. The doctrine of phlogiston lessening the capacities of bodies for containing heat, as stated by Dr. Crawford, has been opposed with great force of argument by Mr. Morgan, and others, who cannot find that the capacities of bodies for containing heat are so greatly altered by means of phlogiston as Dr. Crawford pretends to have found by experiments. Perhaps the following considerations will tend, in some measure, to clear up this matter.

I am inclined to think that the heat in combustion comes from the air, as I formerly suggested \*; but yet I think that we must consider heat, or fire in *two different states*. When it is set free, it then manifests itself as heat ; becomes sensible to the feeling, and the thermometer ; and different bodies have different capacities for containing it, the same as they have for containing *moisture*. A sponge, for example, has a greater capacity for containing water, or *moisture*, than

\* Though phlogiston (or the inflammable body) may extricate heat from *air* and *some other substances*, it may not from *all*. The fixed alcali extricates the calcareous earth from many substances; but there are others to which it has a less affinity than that earth; and there are other instances of the kind to be met with in chemistry. On the following theory also the capacity of a body for containing *heat*, does not depend on its quantity of phlogiston.

ivory or wood. But when fire is *chemically combined* with bodies, it then, I think entirely loses its property of *heat*, even as water does that of *moisture* when combined in quicklime, or guaiacum wood. It is then no longer sensible to the feeling, or the thermometer, any more than moisture in like circumstances is to the hygrometer, and of course is by no means discoverable by the methods of finding the capacities of bodies for containing disengaged fire, or *heat*. This difference is so very obvious, that I wonder it had not occurred to me before.

A body therefore may contain an immense quantity of fire, in a *fixed*, or *combined state*, and yet its capacity for containing *heat* may be very little. When that fire is disengaged, and set loose by the addition of phlogiston, or otherwise, it shall then occasion a very intense *heat*, and yet its capacity for containing heat shall not be found to be lessened; it may even be increased.

The capacity of *nitre*, for example, is much less than that of water; yet when nitre is mixed with a combustible body, and fired by a spark which may be considered as nothing (for the least spark will equally fire an 100 weight, and a grain,) a very great degree of heat indeed is generated. I cannot find however, that the capacity of the residuum, of the Clyssus, or of the air generated, is less than that of the mixture was before the

conflagration; and that no heat was absorbed from the neighbouring bodies is evident, because the conflagration happened almost in an instant; and bodies are a long time in imbibing heat from the surrounding substances, as is evident from a mixture of spirit of nitre, and snow; the capacity of which being increased, does not become saturated till after a very considerable time.

No one, however, will dispute that the heat in the above instances came from the mixture of the *nitre* and the *inflammable body*; and I account for it by *supposing* that the latter displaces the fire *chemically combined* in the acid (or *dephlogisticated air*) of the former; all of which (except perhaps what the inflammable body absorbs in lieu of its *phlogiston*) becomes then disengaged fire, or sensible *heat*, agreeable to the theory above premised; and which I was led to by the consideration of the analogy of water or *moisture* in like circumstances.

Though therefore Mr. Morgan, and others, have found that *phlogisticated* and *dephlogisticated* airs have not their capacities for containing *heat* sensibly different, the latter may nevertheless contain a very great quantity of fire in a state of *chemical combination*; and its being extricated by the inflammable body may be the principle on which the *heat* in combustion depends. The like may be observed with respect to *animal heat*, &c.

If it be contended that the *phlogiston* itself, when disengaged, is *heat*, and that it is disengaged by the *pure air*, or other principle, attracted by the basis of the inflammable body, the argument will still hold good, viz. "That the " phlogiston, while in its state of *chemical combination*, is not discoverable by the methods " whereby we detect the capacities of bodies for " containing *heat*." But the former opinion is that to which I am rather inclined.

I cannot but add however, that I have lately learnt that it is the opinion of M. Lavoisier, and others, that there is no such thing as *phlogiston*, in the sense in which we use the word. They account for combustion by saying, that the dephlogisticated air unites with the inflammable body; and hence the increase of weight of the calces of metals, and of the acids of phosphorus and sulphur, &c. They even explain the acidity of these acids by imputing it to the dephlogisticated air combined with the inflammable substance.

I am inclined to think therefore, that dephlogisticated air is the *principle of acidity*, neutralized with *fire*. That the inflammable body displaces the latter from the former, which it attracts by a superior affinity; and hence the *heat*, and *diminution of air* in these cases, as well as the *increase of weight*, acidity, &c. Hence also de-

phlogisticated air may be recovered from the acid, when properly circumstanced, by means of an intense *heat*. But I mean to consider this matter, and also the question concerning the existence of phlogiston, more attentively at my leisure.

Page 85. Heat has hitherto been generally considered as an *agent*. Ought it not rather to be considered as a *principle*? For example, when we find that *cold* water will not dissolve cream of tar-tar, but that *hot* water will, ought it not to be said that water alone is incapable of dissolving that salt, but that it is rendered capable of it by the intervention of a sufficient quantity of heat or *fire*? — So water will not unite with oil; but if an alcali be added, it will; the alcali, being attracted by both, acting as an intermedium. If the alcali be withdrawn from the compound, the union is dissolved, and the water and oil separate. So if the above solution be exposed to the cold, the fire, or heat, which served as an intermedium, being attracted away by the surrounding bodies, the water, and salt, separate. In some cases the heat is so strongly retained, or fixed in the compound, that no decomposition takes place on exposure to cold, the surrounding bodies not having power to attract away the heat or *fire* so fixed. The like may be observed of bodies not burning but in a certain degree of heat; and of many

many other instances to be met with in chemistry. Again, heat or fire decomposes many compounds. Is it not because one of the ingredients has a greater affinity with it than with the principle it is already united with ? The fire or heat, in some cases, is attracted away by the neighbouring bodies on exposure to cold, and the body is again capable of uniting with the principle that was expelled by the heat ; but in other cases this does not happen. Heat or fire therefore seems to act in the same manner as other chemical principles.— If vitriolic acid be combined with water, its activity is very great. If it be transferred to metals, earths, &c. its activity becomes less and less, till at length it is imperceptible. If the same quantity of *fire* be transferred from some bodies, to others, in a like succession, according to their capacities for containing *heat*, the activity of this principle is, in like manner, decreased. For *fire* to appear as *heat* therefore, must it not be *dissolved* in bodies ? And is not its activity more restrained, in proportion as bodies attract it more strongly ? The dispute “whether heat be a *quality*, “or a *substance*,” may, perhaps, be settled by these considerations.—If vitriolic acid air be added to water, it will be dissolved; and the water will be more strongly impregnated with its acid virtue as more is added ; but when the water is saturated, the acid flies off in the form of *air*. If fire be added to a body, it is dissolved by it, and thereby con-

tutes *heat*, which is greater, in proportion to the quantity of fire so *dissolved*? But if the fire be added beyond a certain proportion, does it not fly off in the form of *light*? (The red-making particles first, and the others afterwards? \*)

Page 85. In addition to the note at the bottom, it may be observed, that it has been found by a foreign philosopher, that solid bodies expanded by *force*, break exactly at that point of expansion at which they would become fluid by *heat*. But I have even yet no decided opinion in regard to the hypothesis suggested in that note.

Page 102. It may be added, that fermentation, putrefaction, &c. are the great means employed by nature for resolving animal and vegetable bodies into their principles.

Page 107 and 112. See also note, p. 272.

Page 219. The *elasticity* of muscular fibres is independent of their *irritability*. The muscles of some fishes, &c. are not elastic, or but very little so. Where much strength is wanted, *elasticity* is bestowed. Thus, the muscles of the leg  
of

\* Thus also *light beats bodies*. — If electricity, in electrics, condenses into *light*, and *dissolves* into *heat*, (as vapor, by cold, returns to water) does it not argue that *light*, *heat*, and *electricity*, are the same principle, only in different circumstances? I mean to consider this subject also, more particularly at my leisure.

of a bullock are more elastic than those of the buttock; of a small fish, than a horse, &c.

Page 221. The muscles served by the second and third sets of nerves are now defined by physiologists as having, the one *original* motion, the other *voluntary* motion, or depending on the brain.

Page 222. On the meeting or union of nerves serving different parts, as in ganglions, &c. the sympathy of parts with one another seems to depend.

Page 250. The dark red colour of the venous blood seems, by comparing it with the colours of a soap-bubble, to be of the *first* order, that of blood reddened by air of the *second*, the direct contrary to what we might expect from this doctrine. This led me to ask, whether the blood does not acquire some principle from the air in lieu of its phlogiston, so as even to make the particles *larger* than they were before. When white metals are calcined, their colours are changed from the white of the *first* order to some colour which argues a greater thickness of the particles. And it is now known that they attract pure air, or some other, from the atmosphere in lieu of their phlogiston, by means of a double

double affinity, and thereby become heavier than before. The latter is also the case with the acids of phosphorus, and of sulphur, as already observed. It seemed to me, from the above change of colour, that the case was the same with the blood. Is it not *dephlogisticated air* that is thus attracted by the blood? For that is the principle which the air loses by *respiration*\*.

If this be the case, animal heat may be accounted for in the following manner. Dephlogisticated air is attracted by the blood in the lungs in its *undecomposed state*; hence the redder colour †. As the blood circulates in the body, this dephlogisticated air is *decomposed*. Its *acid principle*, or basis, unites with the phlogiston, or light, from the nerves or fibres, if the theory of motion formerly suggested be true; or else is attracted by means of a superior affinity, into the fibres, or other parts of the

\* When blood is first drawn from the veins, it is of a dark red colour. By exposure to air, it becomes florid. But when it begins to putrefy, it becomes dark coloured again. It has been said that the globules are *broken down*, but ought we not rather to say, that they are *revived* (by the phlogiston disengaged by the putrefaction,) and that like metals, they then give out again the air they had attracted in lieu of their phlogiston? This, however, is offered as a mere conjecture.

† Nitre, and other saline matters, also redden blood.

system,

system, and its *fire* being thereby set free, occasions *the heat of the blood*\*.

When animals are placed in a higher temperature they generate less heat than when placed in a colder one. Dr. Crawford has found that the colour of the venous blood is more florid in the former case than in the latter; had not less dephlogisticated air in the blood therefore been decomposed, and of course less heat generated? This, together with the difference of evaporation by the lungs, and surface of the body, in these cases, seems to account for animals always preserving the same temperature.

But the mere causing of animal heat, does not by any means seem to account for respiration being so absolutely necessary to life that an animal cannot exist even a few minutes without it. Besides animal heat therefore, I had formerly ventured to suggest whether *animal motion*, or the action of the muscular fibres, on which the circulation and life immediately depend, was not also connected with this function? The following is also submitted to the reader.

The heat of animals seems to be in proportion to the quantity of air which they breathe. The quantity of air breathed, or in other words, the

\* Or does the air extricate the phlogiston from the nerves, fibres, or other parts, in the form of heat? If it be true that phlogiston is fixed heat,

quantity of dephlogisticated air contained in the arterial blood of animals, seems to be in the *direct* proportion to their *heat*, and in the *inverse* proportion to the *irritability*, or disposition to contraction in the *moving fibres*. Thus, fishes breathe less air than amphibiæ\*, and those less than land animals; and their irritability is, I think, held to be in the contrary order; for which reason also, it seems to be that the motion or pulse of the blood in the aërtic system is less in fishes than in land animals, so as to give less stimulus to their fibres.

To animal motion two things are known to be essentially necessary, viz. *irritability* in the *fibres*, and a *stimulus* in the *blood*. The great and principal stimulus employed by nature in the *blood* is *heat*. The influence of this stimulus is obvious from hence, that if the heat of the *blood* be increased (as in fevers) the action of the *fibres* is also increased, and vice versa. *Heat therefore is absolutely necessary to the continuance of the vital motions*†. And we also find that the heat is in the *inverse* proportion to the *irritability*, as hath already been observed. But to supply this heat,

\* In this class of animals, only part of the *blood* goes to the *lungs*; and on its return is mixed and diluted with the remainder of the mass.

† The voluntary muscles require an additional stimulus from the brain or nerves. Yet they must be previously prepared for the action of that stimulus, by *heat*. See *Essays on Physiological Subjects*.

respiration is necessary? and this seems to shew, that respiration supports life by means of continuing the vital and other motions of the body on the principle above described.

In support of this opinion, it may be observed, that the heat (at least the summer heat) of the atmosphere, is sufficient for the animation of some insects, &c. and hence they have no lungs.

The chick in ovo is heated and *animated* by external warmth, and therefore its breathing is not required. The same is partly \* the case with the *fœtus* in *utero*. Hence after birth, breathing is absolutely necessary to both. These instances seem to demonstrate that motion is dependent on heat, and heat on respiration, as above suggested †.

Many other arguments might be offered in support of this theory, which (at least as far as concerns the connection of respiration with heat, and the stimulus to involuntary motion) seems perfectly simple and obvious. If the doctrine be true, the specific power of the blood in at-

\* The blood of the *fœtus* may also receive a small portion of pure air (and of course latent heat) from the mother, by means of the umbilical vessels.

† The heat of animals is also of use to liquefy their blood and juices; but this does not seem by any means to be the grand use of heat.

tracting

tracting pure air in the lungs, and of parting with it so as to be decomposed in the body, the variations of that power, and their effects on the vital motions, &c. will probably constitute a very important consideration in physic. But all this is spoken with submission to better judges.

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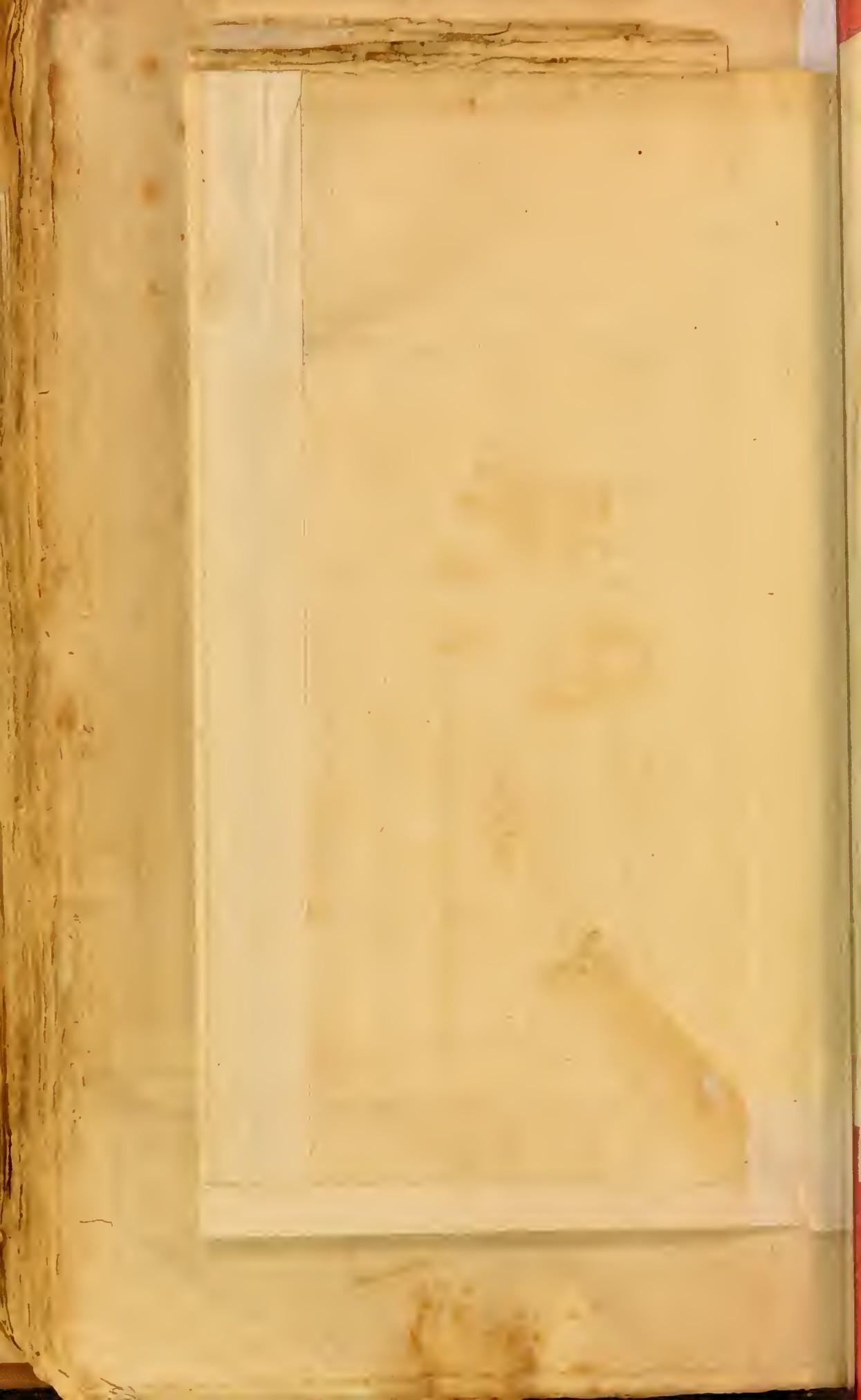
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